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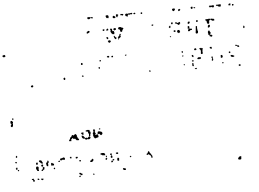

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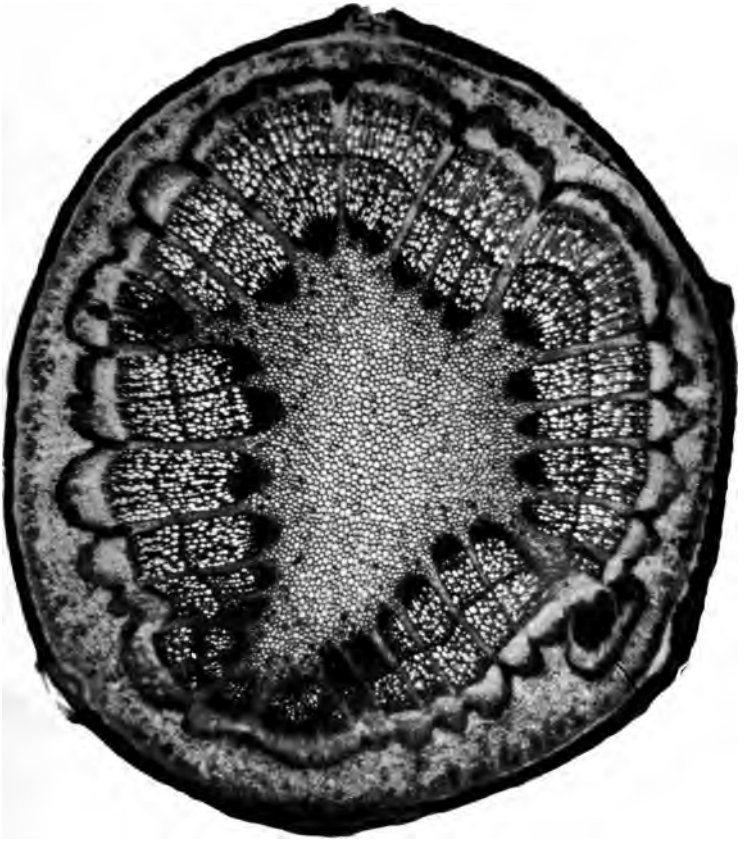

Transverse section of young Beech stem, showing internal structure

Actual diameter $\frac{1}{8}$ of an inch

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MINUTE MARVELS OF NATURE

BEING SOME REVELATIONS OF THE MICROSCOPE

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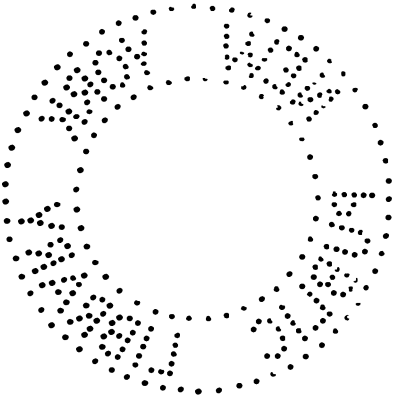

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TO

RICHARD HANCOCK

Honorary Secretary of the "Birmingham Microscopists' and Naturalists' Union" I inscribe this slight introduction to one of Nature's inexhaustible sources of wonder and fascinating interest as an appreciation of his knowledge, skill, kind sympathy, and valued friendship

AUTHOR'S PREFACE

MOST of the contents of this volume originally appeared in *Good Words*, although chapter viii. was published in the *Pall Mall Magazine*, and chapter ix. in the *English Illustrated Magazine*, while Fig. 142 with its letterpress, and Figs. 94 and 95 appeared in *Animal Life*. I have to acknowledge the courtesy of the proprietors of these several publications in permitting me to use them for the present volume.

Each chapter has been revised and considerably enlarged, both in matter and illustration, while the last chapter, with the exception of its first two illustrations and the matter pertaining thereto, is entirely new.

The purpose of this little volume is not to offer even an elementary text-book on microscopy, but rather to present a readable and popular description of some of the innumerable minute wonders that abound in Nature.

To those readers who possess and use a microscope I trust that my work may increase their interest in the fascinating study; while for those who do not the large number of illustrations will to some extent enable them to realise what the microscope reveals, and may, perhaps, create in them the desire to use it for themselves. And then if this volume is soon laid aside for works more advanced, it will indeed have done good service.

The illustrations throughout are greatly magnified photographs or photo-micrographs made directly from the actual objects, excepting in a few instances where they are stated to be of natural size. The image of the minute object, as seen by the eye when looking into the microscope, is projected directly on to the sensitive photographic plate, the camera occupying the position of the observer at the head of the microscope tube; but to describe the numerous details of the work would be out of place here.

With regard to the minute objects themselves, such as the various plant, insect, and animal dissections, it need hardly be said that considerable care is required to prepare them for photographic purposes.

While using a large number of my own preparations, I have to acknowledge the kindness of Messrs. W. Watson and Sons, of 313 High

Holborn, W.C., for permission to photograph their diatom preparations in Figs. 13 and 15; also of C. Baker, 244 High Holborn, W.C., for the use of all the preparations illustrated in chapter iii., except Figs. 44 and 52; and likewise of Mr. C. E. Burnell, of Henley, Shepton Mallet, for the use of the insect dissections shown in Figs. 120, 136, and 163; and lastly, of Mr. R. Hancock, of Handsworth, Birmingham, for the various preparations shown in Frontispiece and Figs. 27, 28, 29, 38, 104, 112, 116, 118, 123, 124, 125, 127, 130, 144, 147, and 161.

I am also greatly obliged to Mr. E. Kay Robinson for his most helpful revision and emendation of my work.

J. J. W.

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CHAPTER I

THE BEGINNINGS OF PLANT LIFE

At the end of my garden, facing full south, stands an old wooden fence. Nothing could appear more thoroughly and completely dead than a paling which is beginning to decay; but if you will come with me to the fence I will show you more living plants than you could observe in a bird's-eye view of the whole of Kew Gardens. Many of us think of "plants" only as the flowering plants which are put in our garden, and we should see no absurdity in remarking that a flower-bed contained "more weeds than plants;" while very few would enumerate more than trees, shrubs, herbs, grasses, ferns, and mosses as classes of plants. Yet only a very small proportion of the world's plant life, so far as numbers go, assumes these prominent forms.

The sea, for instance, is sometimes conspicuously tinged in large patches, upon which inexperienced passengers gaze in wonder from the steamer's deck, by plants. You may fill a tumbler with the

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coloured sea-water, and no matter how closely you look, it still seems only coloured water. But the colour is due to incalculable multitudes of tiny plants, living their separate sea-lives as completely as the great whale himself. In the same way a coloured stain will creep over damp walls, the bark of trees, or this old fence of mine, where myriads of microscopic plants are congregating together and multiplying very rapidly.

For the infinite variety of form and habit that plant life assumes adapts it to flourish in sites where life of any kind might have seemed impossible. Leathery and powdery plant-incrustations cling to the hardest rocks and stoniest soils; vegetable moulds take up their abode on almost every perishable article; trees and ships are often completely destroyed by a plant multitude known as "dry-rot"; while smut, rust, bunt, and other familiar forms of parasitic fungi, prey upon living plants to such an extent as to spoil and destroy whole crops of grain or fruit. What seems worse still is that many of them not infrequently invade the organs of living animals, and are the known causes of many diseases. A single drop of pond, river, or sea water will often reveal multitudes of varied plant forms; and, in short, it is difficult to point to any natural condition of land or water

that is free from plant life. Its germs, or spores, fill the air we breathe and are consumed in all the food that we eat. The very ground we stand upon may be built up of tiny plants, as I will show later.

While mentioning fungi, moulds, and other

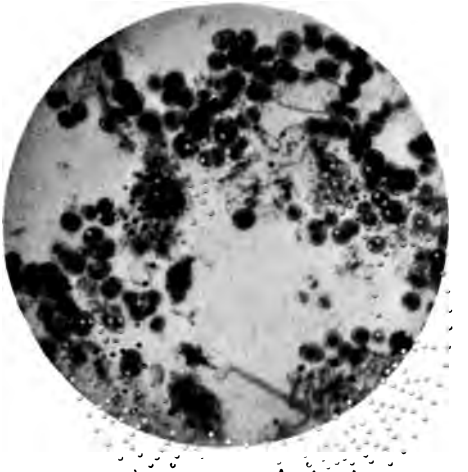

Fig. 1. Microscopic unicellular plants, multiplying by division of their cells

parasitic organisms as being representative of plant life, it is not my purpose here to consider this class of plants, but rather those which may be regarded as leading the way to the higher plants, by their possession of the important green colouring-matter known as "chlorophyll," or its

equivalent; of which I will speak in a later chapter.

Almost all damp situations and standing waters, such as rain-water cisterns, drinking-troughs, wet ditches, ponds, &c., will provide examples of minute algæ, or the earlier forms of plant life. And these, like the green film on the fence, will be mostly unicellular plants—each microscopic cell constituting an individual plant, which eventually divides into two or four similar cells, with the same power of division (*see* Fig. 1).

Sometimes the newly formed cells have long cilia, with which they swim freely about in water; and stagnant ponds often owe their green hue to myriads of these active green cells swimming gaily about within them. When shown under the microscope, perhaps the last thought that would occur to the inexperienced observer would be that these wonderful little organisms are plants at all; and as there are large numbers of lowly plant forms that can move about in water, and are almost invariably found in company with minute animalcules similarly endowed, even experts are often puzzled to decide to which kingdom the tiny living forms belong. So it comes about that many of these organisms have been bandied about by learned scientists from the Animal to the Vegetable Kingdom and back again, until the

ordinary student scarcely knows where to locate them.

In recent years, however, a better understanding has been arrived at with regard to the more

Fig. 2. Desmids (*Closterium lunula*), or unicellular plants, found in standing waters. Actual length about $\frac{1}{60}$ of an inch

familiar forms, since a large number of these gaily swimming organisms have been shown conclusively to belong to the Vegetable Kingdom.

Fig. 2 shows a number of the singular unicellular plants which are called "desmids." These are minute fresh-water algæ, of a beautiful green colour and numerous diverse forms.

Every moderately clear pool or ditch will provide examples of these interesting plants, and they especially abound in ponds which lie in exposed and bleak situations. The species in the illustration is characterised by its crescent-like form. Each cell is free and able to move about in the water by a curious, feeble movement, and if kept in a glass vessel they all move slowly to the side next to the light and congregate there. For a period of over twelve months I kept a large quantity of these desmids propagating in a common glass jar, having accidentally gathered a few attached to some of the common duckweed which floats on ponds.

Desmids, like other green plants, evolve oxygen in sunlight ; and so, together with the duckweed, which also multiplied in the glass jar, the water was kept fairly pure, and the desmids increased at such a rate as to completely line the sides of the glass vessel with a film of bright green colour.

A desmid cell possesses a thin outer coating or cell-wall, sometimes adorned with spiny projections or markings. Surrounding this, a transparent film of gelatinous matter is recognisable, although sometimes only by its preventing the cell-wall from touching external objects. Inside the cell-wall proper is a layer of colourless protoplasm, which encloses the mass of green-coloured

living substance of the cell or plant. As these plant cells all show more or less clearly a line of division in the middle, they might seem to be two separate cells joined together; but such is not the case, each desmid being but one cell.

When reproduction is about to take place, the

Fig. 3. Other forms of desmids, chiefly *Micrasterias denticulata*. Actual length about $\frac{1}{100}$ of an inch

contents of the cell divide into the two halves, which seem to draw away from each other, and so become constricted towards the centre, and finally break away. Each irregular half then soon develops the symmetrical crescent shape.

The above example (Fig. 3) is taken from

other species of desmids which present a somewhat different method of reproduction. Instead of breaking away and subsequently acquiring a complete shape, the two halves remain together, but gradually develop at their line of junction, two little rounded discs touching each other at the edge, which gradually become larger and push each other further apart, until, finally, the indentations round the desmid's edges appear, after which the two halves become detached as perfect desmids.

There are other and more complicated methods of reproduction and cell division even with this same *Micrasterias;* but these need not concern us here, though they show that even these lowly, single-celled plants gradually approximate in structure and methods of reproduction to higher and more complicated forms. And it should also be observed with regard to these delicate and beautiful organisms, how frequently symmetry and regularity of form prevail. But this we will consider more in detail hereafter.

Meanwhile let us glance at some of the most extraordinary forms of the invisible vegetable world—tiny unicellular plants of almost unimaginable minuteness, called "diatoms."

These microscopic and wonderful algæ are abundantly distributed in nature. Wherever

exposed water is to be found, diatoms may be looked for, whether it be stagnant or running, salt or fresh, warm or cold. Even the melting snow on the summits of the highest mountains, or the water that lodges in your rain-water spout, frequently contains diatoms in abundance.

As the water evaporates, these invisible plant particles become dry, and by reason of their lightness and tenuity get wafted, still alive, from one region to another by the high winds. The hottest sun and bitterest cold does not affect their vitality. As the air calms they settle down again, and after months of frost or scorching sun, given moisture and sunlight, they again rapidly multiply, and so become distributed everywhere.

When considering the desmids I mentioned that the cell-walls sometimes developed spines or markings on their surface. Now diatoms present most extraordinary and remarkable features in this respect. Each little vegetable cell that constitutes a diatom has the power to absorb from the surrounding water that chemical combination termed "silica" or flint, a small proportion of which exists dissolved in most natural waters. The silica which it thus appropriates becomes deposited regularly on the cell-wall, and so the single vegetable cell becomes clothed with an almost indestructible flinty armour. But this is

not all ; one side of the shell or frustule becomes slightly larger than the other, and fits over the smaller, after the manner of the halves of a pill-box or canister.

On the surfaces of these flinty shields delicately carved and chased symmetrical markings

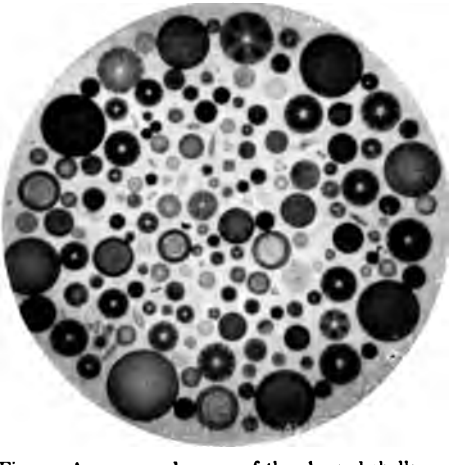

Fig. 4. An arranged group of the cleaned shells, or shields, of the tiny plants called "diatoms." The actual group measures $\frac{1}{12}$ of an inch in diameter

are revealed when considerably magnified. An arranged group of these tiny and wonderful shields is shown in Fig. 4.

As this group measures only one-twelfth of an inch in diameter, it will be understood that the shields are considerably magnified, although but

the faintest indications of their fascinating sculpturings are visible.

The refined nature of some of the markings of diatom valves defied the powers of the best microscopes for many years, and even with the finest of modern lenses most skilful manipulation is required to bring out their details of structure. In fact, the more delicate forms are used by the makers of microscopes for testing the accuracy of their work.

A very remarkable fact regarding these minute sculpturings is that frequently, as the magnifying power is increased, new and unsuspected details of structure become visible. What were minute rows of dot-like spaces reveal, when enormously magnified, other perforations and sculpturings within them of equal beauty and symmetry.

And, when we have exhausted the powers of our best optical instruments, who knows what lies beyond? If unsuspected marvels of fascinating minuteness have been revealed with the advance of modern instruments, one cannot help wondering where this decoration ends. The methods by which these tiny plants construct their almost indestructible shells defies all attempts to explain; and in saying "almost indestructible" I am well within the mark, for these silicious frustules, or

valves, resist putrefaction almost indefinitely; and as the organisms multiply very rapidly by subdivision, and keep falling in a steady shower to the bottom of the water as they perish, layers of these

Fig. 5. Some diatoms (*Pinnularia nobilis*) shown on a dark ground to illustrate their glassy nature. Individuals vary in length from $\frac{1}{80}$ to $\frac{1}{160}$ of an inch

glass-like shells gradually result in considerable deposits of solid flinty material which resists acids and even the dull red heat of an ordinary fire.

The familiar polishing material "rotten-stone" or "Tripoli," large deposits of which occur in Bohemia and other parts of the world, is a soft friable rock which chemically is almost pure silica; but the microscope reveals the fact that it is not

ordinary silica, but is built up of the tiny and beautiful silicious shields of diatoms. And as the forms found in rotten-stone are characteristic of fresh-water species, we conclude that where the deposits are found lakes or marshes existed in previous ages.

In long periods of time, by the slow percolation of water, these diatomaceous deposits (a minute speck of a diatom deposit composed almost entirely of one species is shown in Fig. 5) are slowly dissolved and then redeposited as a hard opal-like rock. Thus these apparently insignificant plant atoms, by their vast numbers and rapidity of multiplication, play most important parts in the formation of the earth. The city of Richmond, in Virginia, is said to be built on a stratum of diatoms 18 feet thick. Estuaries and harbours are frequently considerably shallowed by the accumulation of these flinty deposits, and the surface and ooze of many seas reveal diatoms in abundance.

Fig. 6 shows diatoms dredged from the Atlantic by the *Challenger* at a depth of 1990 fathoms, or just over $2\frac{1}{4}$ miles.

The variety of forms assumed by the frustules, or shields, are as varied as their surface markings, and quite beyond description. The most familiar species found in ponds assume the long oval or boat-shaped forms, such as those shown in

Figs. 5 and 7, and many are extremely delicate; but all alike possess their characteristic wrink-

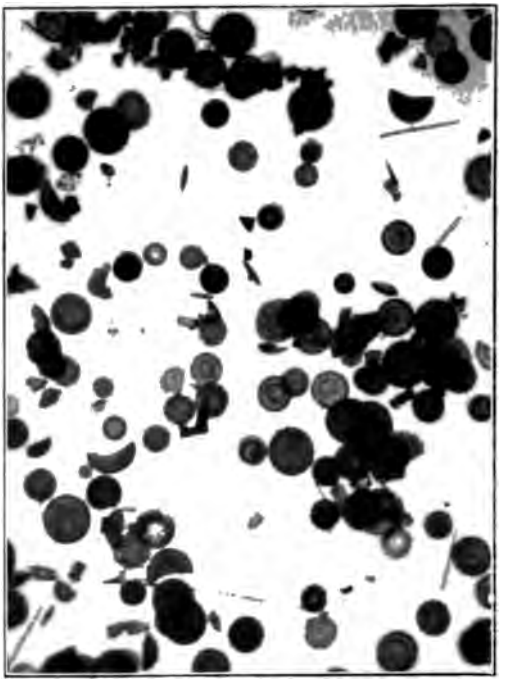

Fig. 6. Diatoms dredged from the Atlantic at a depth of about 2¼ miles

lings, dottings, and markings, when highly magnified.

It is extremely interesting to watch the peculiar gliding movements of some of these boat-shaped

atoms. Without any visible effort or means of propulsion they slowly glide in a straight line through the water, and should anything obstruct

Fig. 7. Diatoms common in ponds and lakes

their passage they make no effort to round it, but without turning reverse their motion and glide backwards, apparently on the same straight track on which they came, often repeating the movement several times as if unconvinced that the path was impassable.

Other common forms do not lead such a free

Fig. 8. Chains of diatoms in their natural state adhering to a larger microscopic alga, magnified

life, but remain attached, and form chains of somewhat oblong or square frustules, each adhering to the other at the corners, the chains ultimately being fastened to, or intermixed with, other

and larger algæ or aquatic weeds. Fig. 8 shows an example of diatom chains in their natural situa-

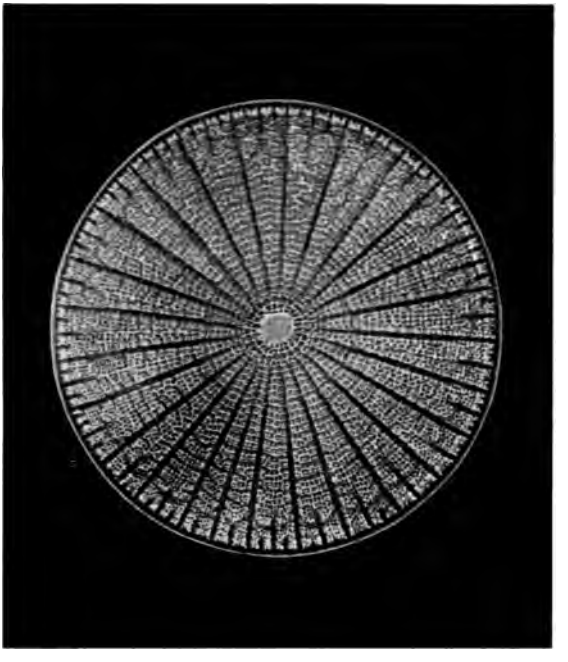

Fig 9. An individual diatom-shield (*Arachnoidiscus Ehrenbergii*) immensely magnified

tions, clinging to a much larger alga, although the portions shown of this are really microscopic. Others develop foot-stalks, by means of which they attach themselves to stones, &c., and so form little groups or clusters.

The beauty of the markings of the frustules cannot be readily seen in the living diatoms; but the skeleton shields, when cleansed of their living matter by heating to red heat or dissolving by

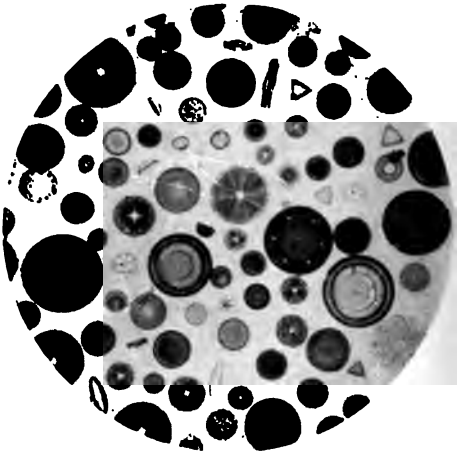

Fig. 10. The central portion of the group of silicious diatom-shields shown at Fig. 4, more highly magnified.

nitric acid and magnified, reveal to perfection their wonders of symmetrical precision and minuteness. One of the cleaned shields from a marine form is exhibited in Fig. 9. Two hundred of these, placed edge to edge, would scarcely extend one inch; yet this is a very large form, comparatively speaking. The lines and markings on some species are estimated at about 1-76,000th of an inch

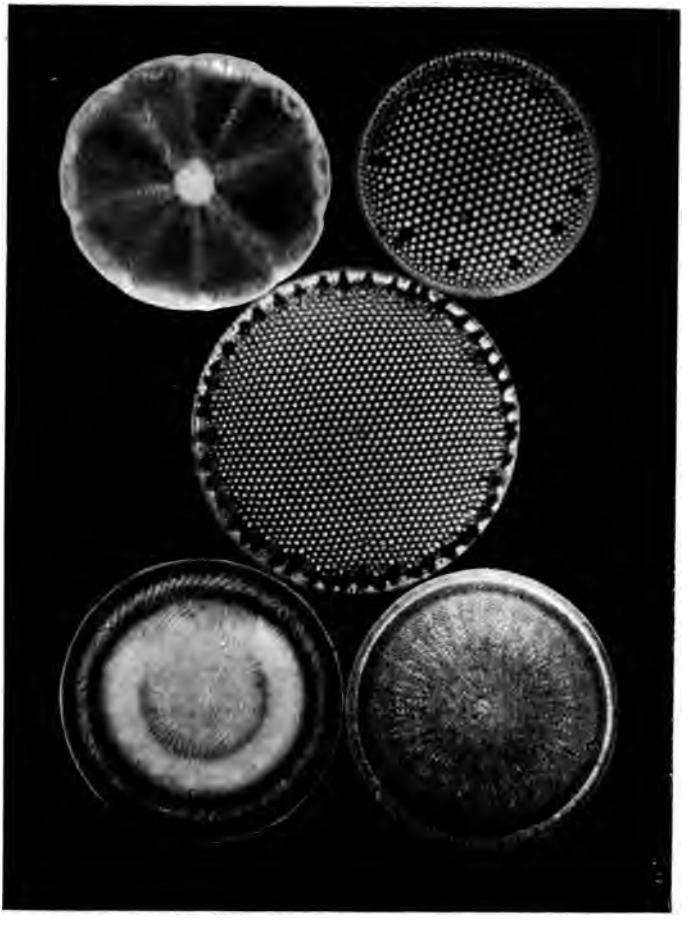

Fig. 11. A few selected diatom-shields from the central portion of Fig. 10 again shown under increased magnifying power

apart, so that a hair from the human-head cut longitudinally into 400 thin slices would approximately fill the spaces between 400 of these marks.

We cannot here even glance at the life history

Fig. 12. Several diatom forms from the top central edge of Fig. 4 immensely magnified

and methods of reproduction of these lowly and beautiful unicellular plants. The subject is so great and their species are so numerous that we should require a separate chapter; so I must be content to call attention to their beauties, which show that the lowest and most minute forms of plant life present no less wonderful intricacies of structural detail than the highest and largest.

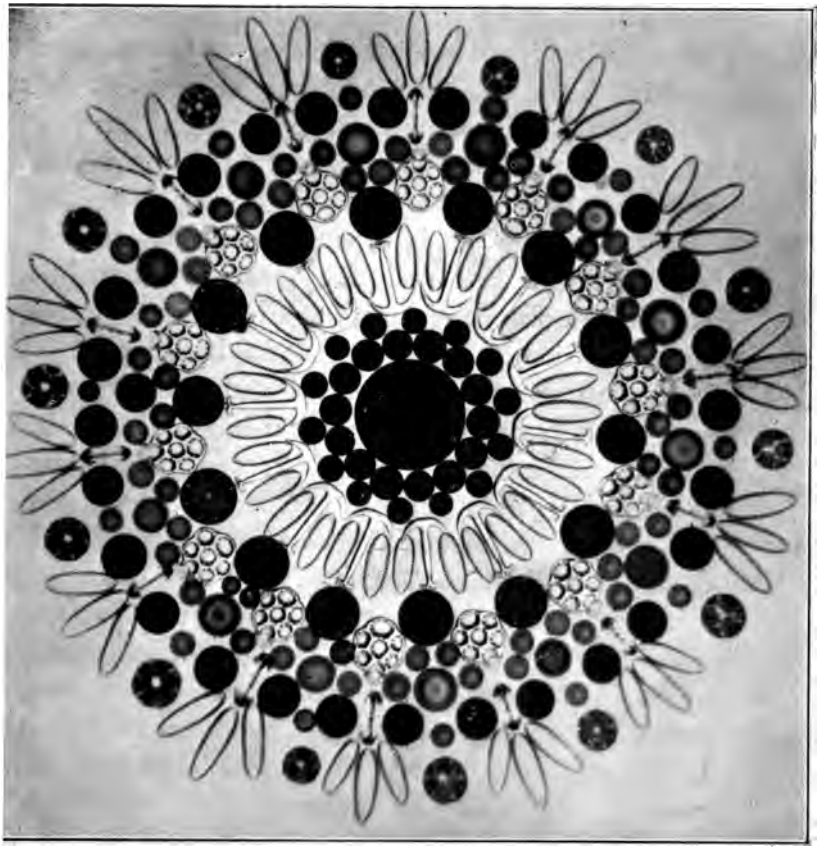

Fig. 13. A group of cleaned diatom-shields arranged in an artistic manner within a circle actually measuring only $\frac{1}{8}$ of an inch in diameter

As an instance of the revealing power of the microscope, I will again call my readers' attention to Fig. 4, and ask that it may be compared with Fig. 10, which represents the central portion of the same group still more highly magnified, showing how further details of structure are brought out by the increased magnifying power. And again in Fig. 11 a few forms selected, but rearranged, from the centre of Fig. 10, are shown under considerably greater magnifying power.

Fig. 12 shows another combination immensely magnified from the top central edge of Fig. 4 group, the members of which can readily be identified by their relative positions. These will serve to give an idea of the beautiful and wonderful frustules or shells of diatoms.

It may occur to those who study these illustrations how beautifully these diatom shields stand apart in the groups, or how prettily they are arranged. It is true that they have been arranged in these forms. Here we get an instance of man's skill with the minute, for all these diatoms have been individually selected as perfect forms, and carefully placed in their relative positions.

Fig. 13 shows a beautiful group of diatom valves, arranged in a symmetrical and artistic manner by one skilled in this work. The actual group

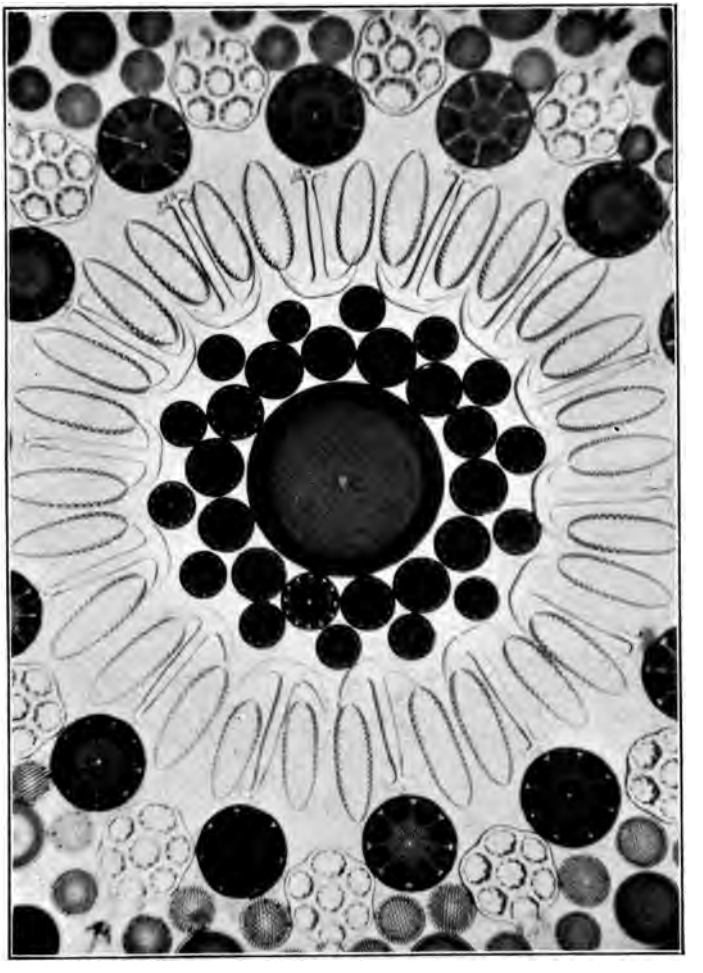

Fig. 14. The central portion of the group Fig. 13, again more highly magnified

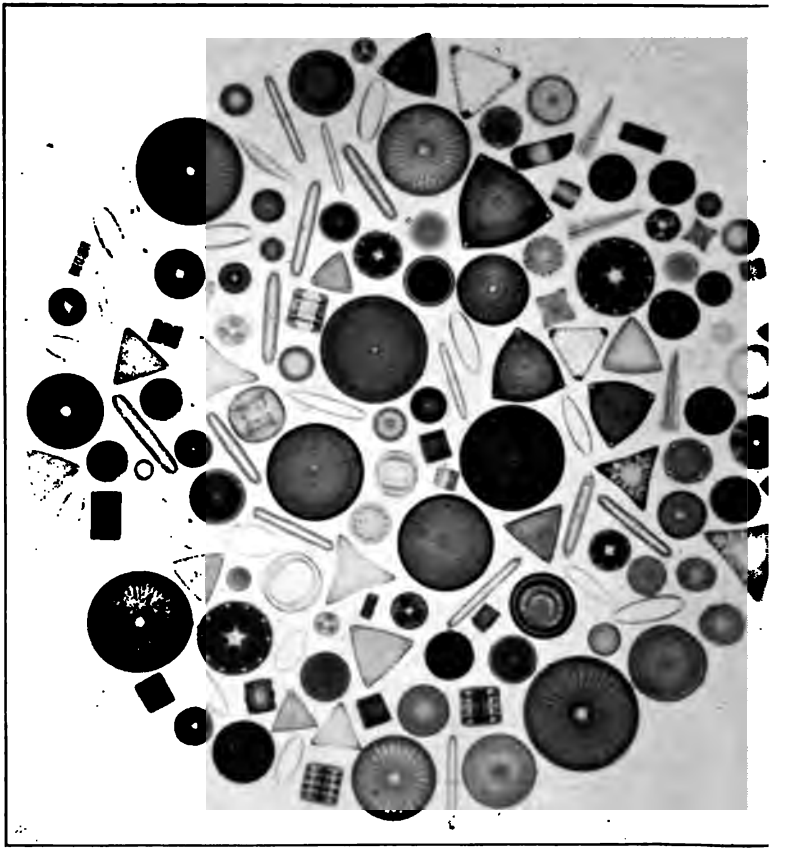

Fig. 15. Another diatom group, also arranged within a circle of $\frac{1}{8}$ of an inch in diameter

measures one-eighth of an inch in diameter, every individual specimen having been placed within this small compass. This is truly very wonderful work; but when we magnify these exquisite atoms and see their marvellous, symmetrical patterns, thousands of times smaller yet perfect withal, we see how insignificant man's most clever and ingenious efforts become in comparison with Nature's humblest works.

The central portion of this prettily arranged group is shown more highly magnified in Fig. 14; and to exhibit the infinite variety of form and design in these fascinating plant atoms, another wonderful group is illustrated in Fig. 15, which also is arranged within a circle one-eighth of an inch in diameter, while a portion from near the centre of this is again further magnified in Fig. 16.

In conclusion, we may glance at a few forms of algæ that show a further advance in plant form; that is, an advance on the single cell.

We take from almost any pond some of the common green slime almost invariably found in such localities. On examining this material we find long strings or threads of vegetable cells, all alike and joined together, as is shown in Fig. 17. When these thread-like plants are about to propagate or multiply, corresponding cells in

Fig. 16. A portion from near the centre of group Fig. 15, more highly magnified

individual threads, as they rest beside each other, throw out tiny tubes which eventually meet. The cell-walls between them then dissolve, and the contents of one cell pass into the other. This process is shown taking place in our illustration; and it results in the formation of a spore for a future plant, which by subdivision of its primary cell becomes a thread-like plant like its parents.

From this stage in plant life a gradual evolution of form and specialisation of cells begins to take place, and in forms slightly higher in the scale certain cells are told off to attach those simple-celled plants to fixed objects, and so we get the first indications of the roots of the higher plants.

It does not follow, however, when plants are composed of a number of cells, that they necessarily give up the habit of free movement. At Fig. 18 is shown an example of one of the most beautiful and interesting examples of pond algæ. This little plant is just visible to the eye as a tiny green rolling sphere. When viewed by the microscope, other smaller spherules can be seen within, through its transparent walls. The surface wall of the sphere is covered with a delicate network of protoplasm, dotted with minute green cells, each of which carry two fine threads or "cilia," and it is by means of the rapid

vibrations of these that the plant rolls itself through the water.

This little plant is often abundant in ponds, and in reality is a rounded colony of vegetable

Fig. 17. Thread-like plants, composed of vegetable cells attached to each other (*Spirogyra*)

cells; only a few of which take part in reproduction.

Other forms again show indications of the stem (see Fig. 19) by producing a row of supporting cells which take no part in reproduction, this being left to the rows of cells that they support. As our concluding example, a still more advanced type shows a differentiation in the structure of

its stem, possessing a central system of cells, with a protective outer layer of other cells, and so something akin to the bark or skin of the higher plant forms appears. Fig. 20 shows an alga possessing this first differentiation in stem

Fig. 18. A many-celled globular plant (*Volvox globator*) which swims about in ponds. Actual size about $\frac{1}{40}$ of an inch

structure. Advancing structure may readily be traced, although all algæ are still of lowly form, for even with our last example, each disc on its stem is but a cluster of simple thread-like cells all radiating from the one point.

So we may trace a gradual rise from the lowest to the highest forms of life, and learn to recognise

that all life is akin. No isolated and unconnected instances occur, although it is not always perhaps possible to link up our chain and trace direct

Fig. 19. A lowly aquatic alga, showing the early stages in the evolution of the plant stem (*Draparnaldia*)

connection between the beginning and the end. Yet surely there is enough evidence to show that Nature is one harmonious whole. Breaks which are difficult to explain may occur here and there,

but time and advancing knowledge will reveal much.

Fig. 20. Another aquatic alga that approaches nearer the higher plant forms by a differentiation in the cellular arrangement of its stem cells (*Batrachospermum*)

CHAPTER II

GLIMPSES INTO PLANT STRUCTURE

In the first chapter I mentioned that the common green stain which coloured the damp portions of my old wooden fence was made up of myriads of individual living plants, and that these probably reproduce to-day that simplest form of plant life from which by natural evolution all the complex and specialised trees and herbs around us have gradually risen. Some of the simplest forms I have already illustrated: but in view of the dignity of their relationship it may be worth while to consider more in detail these tiny plant-atoms which occupy almost every damp and vacant niche in Nature.

Look at the old fence. A green film has encrusted all the lower part, so far as the damp earth's influence reaches, giving it a bright colour that you can see across the garden. I scrape it with my little finger-nail and the green stuff that comes off consists of many hundreds of one of the simplest of known plants. These are the one-

celled algæ, known to botanists as *Protococcus viridis*. Fig. 21 shows a magnified photograph of this green stuff off my finger-nail, under a medium magnifying power, and reveals a con-

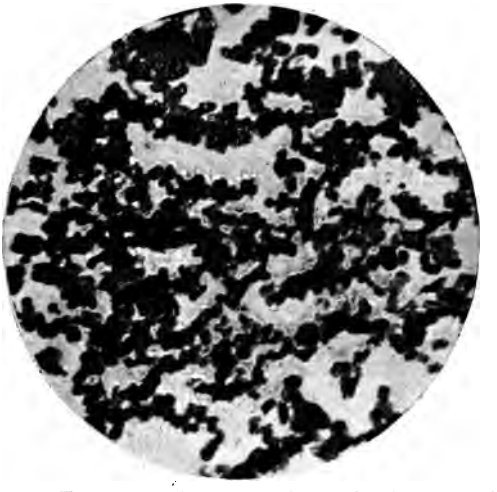

Fig. 21. The green stain on damp fences, &c., is composed of myriads of microscopic plants

glomeration of granules, each granule a plant. If we examine one of these green granules under very high magnifying powers, we find that it possesses considerable structural detail, simple, perhaps, compared with the structure of the higher plants; but then it must be remembered that these tiny living plant-atoms occupy only about one-thousandth of an inch of space.

The envelope or cell-wall which surrounds each granule shows clearly a double outline and contains the life-matter known as protoplasm. Embedded in this can be detected the living life centre of each cell or plant, which botanists term the *nucleus*. Each of these minute atoms of plant life quickly attains to independent maturity, and divides itself by means of a partition-wall which forms like a film of ice and cuts the cell into halves. Each half, when completely separated, very soon divides again; and so myriads of plants are quickly formed, which cover large areas in short spaces of time.

In the Arctic regions early explorers were astounded to find large areas of red snow; but the phenomenon is now familiar to men of science, who know that red snow, like a green garden fence, is due to the presence of unicellular algæ, the only difference being in the colouring-matter of the protoplasm. It is said that acres of snow are frequently covered in a single night by these tiny plants.

Many vegetable cells are so small that over one hundred millions would barely occupy a cubic inch of space; and in each of these the work of life goes on. It is not necessary, however, to examine these exceedingly tiny plants in order to find single cells; nor do they, perhaps, throw

the clearest light upon the ordinary function of the cell in plant-structure. Let us take, instead, from a ripe russet apple, a minute particle of tissue near the core. Fig. 22 shows some of the cells of

Fig. 22. We consume myriads of vegetable cells like these when eating an apple

which it consists. Although taken from the middle of a mass of pulp tissue, it exhibits a conglomeration of single cells, very similar to the algæ previously examined, but much larger. The cell-wall and contents can be well seen, but these cells are transparent and colourless.

Cells, then, are the bricks which build up the plant edifice. The simplest plant is built of one brick, as we have seen; and next in simplicity come plants composed of a few simple cells united together in a chain as previously considered. Complexity begins when a plant exhibits cells of different kinds, each kind fulfilling specific functions in the life of the plant. The apple-pulp cells are very simple in structure, but much more complicated tissues are found in other parts of the parent tree. To show the differentiation of cells for various purposes in plant economy, we may take almost at random any insignificant fragments of any plant.

Every one has observed, for instance, that plants are frequently hairy on leaves, flowers or stems, &c., and Fig. 23 shows a few hairs from the throat, as we call it, of the common yellow pansy. These hairs are in reality single cells, which, instead of remaining as flat skin-cells of the petal, have poked themselves out into elongated shapes with irregular knotted swellings. To the naked eye they look like minute hairs, but under the microscope more closely resemble rugged glass tubes, being quite transparent and filled with granular matter like the cells in their more simple forms. Hundreds of these unicellular hairs, with others of entirely different

forms, are hidden away in the interior of every pansy ; and all serve a purpose in the economy

Fig. 23. Hairs from the throat or interior of the common yellow pansy

of the plant. Otherwise they would not exist, for Nature makes nothing that is useless. No

ornament even exists in Nature without serving some other definite purpose.

And while speaking of ornaments we may look at the surface of a common scarlet geranium's

Fig. 24. The petal of a geranium has a surface of cells like this

petal. How is its invitingly soft and velvety appearance produced? we ask of the microscope; and Fig. 24 shows the skin-cells in this instance, not elongated and hair-like as in the hairs of the pansy, but with central elevations or papillæ, which reflect the light; and so the velvety gloss of the petals of many flowers is effected.

We will take one other simple skin tissue, and

this time a scale from a fern. These broad scale-like appendages correspond to the hairs

Fig. 25. Scales from the frond of a fern, showing their structure

on flowering plants and (Fig. 25) are built up of quite a number of regular cells.

We might multiply illustrations to show how cells collectively compose the various structures of plants, though some become so much altered

that it is difficult to recognise any trace of the original cell-shape in them. By making a longi-

Fig. 26. A longitudinal section through part of the creeping stem of the bracken fern, showing the vascular tubes embedded in the frond tissue.

tudinal section, with a sharp razor, through the growing-point of a plant stem, for instance, we

find that at some little distance behind the growing-point the cells have lost their globular and oval shapes, and are long and thin. This elongation goes on with time, and the connections or division walls which separate adjoining cells disappear, until at last, instead of a network of ordinary cells, we have a series of bundles of long tubes, or "vessels," as botanists call them. Part of such a band of tissue is shown in section at Fig. 26. These tubes, uniting with each other, form the tough fibres that permeate all the principal tissues of higher plants, and in a section of the Sarsaparilla plant-stem (Fig. 27), these "fibro-vascular" bundles—once more borrowing the weird phraseology of the botanist—may be seen scattered in amongst the pith or cellular structure.

These *scattered* bundles characterise the structure of plant-stems in one of the great divisions of the vegetable kingdom, known as the "monocotyledons," which means that seeds, when sprouting, send up a single blade, like a grain of corn, a date stone, or a lily seed. Such plants generally bear leaves with parallel veins, and have their flowers arranged in whorls of three.

These features are in contradistinction to the structure and arrangement of the "dicotyledons," to which belong almost all our common field plants, except grasses, and nearly all our native

shrubs and trees. In Fig. 28 and Frontispiece sections of the stems of sycamore and beech show

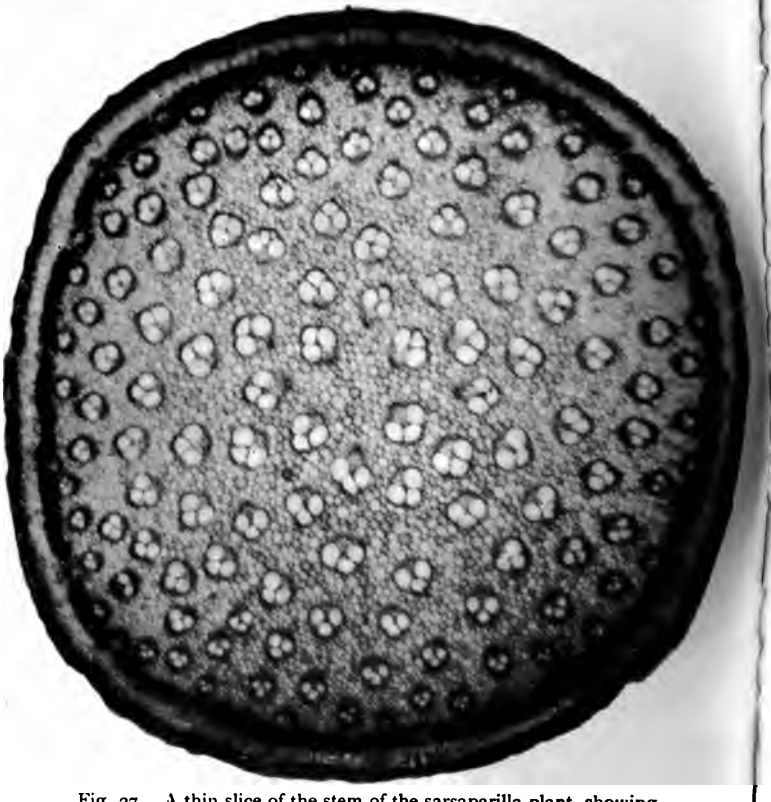

Fig. 27. A thin slice of the stem of the sarsaparilla plant, showing its structure

that the structural arrangement of these plants is more symmetrical and that their vascular bundles

are not scattered about, but arranged around a central pith, each bundle separated from its neighbour

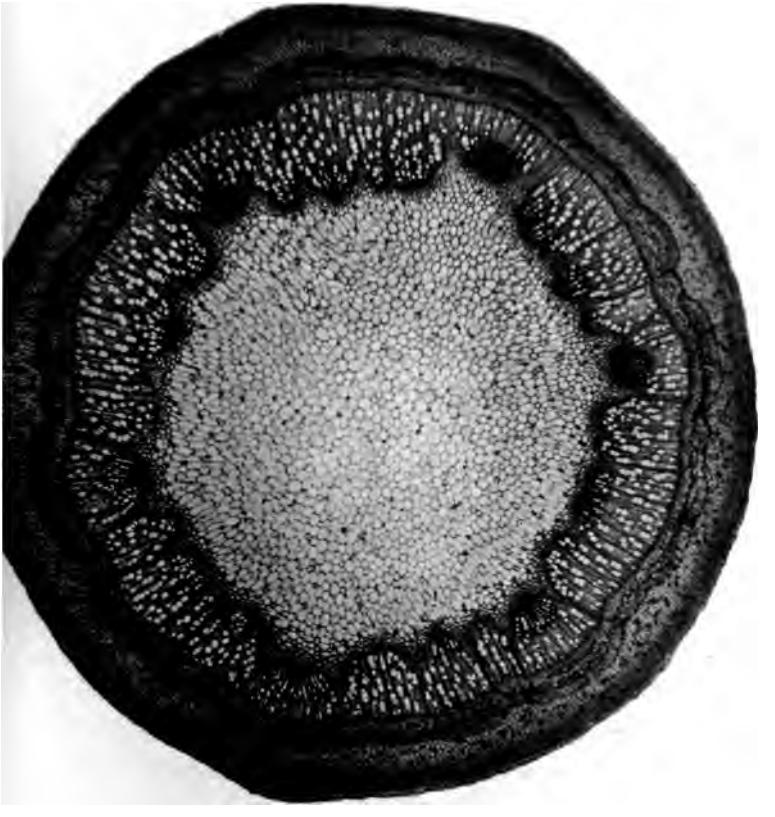

Fig. 28. Slice or section of a twig from the sycamore-tree. Actual diameter $\frac{3}{16}$ of an inch

by a ray from the central pith portion. These features of the stem are generally associated with

the net-veined leaves of most of our English plants and with flowers arranged in whorls of four or five. Thus, as a zoologist can build up an animal from a single tooth, the botanist can, from a thin slice or section of the stem of a plant, at once gain considerable knowledge of the class of plant from which it was taken.

And now just a word regarding these string-like bundles of tissue which we find in the stems and leaves. Each bundle, as I have already shown, originates near the growing-point by the gradual alteration of some cells into long tubes, and on examining these at a later stage, each bundle is seen to consist mainly of two distinct kinds of tissue separated by a layer of delicate cells. The tubular vessels nearest the central pith, when mature, generally lose their protoplasm or living matter, and usually contain air only, although sometimes liquids are conducted through them. Outside these come the wood fibres which give strength to the bundle, and following these the delicate cells which separates one class of tissue from the other. Those vessels on the outer side nearest the bark are similar to the fibrous wood-cells, but more delicate and filled with mucilaginous matter.

Now the layer of delicate cells that separates these tissues is a very important factor to the

plant or tree, and in the growing season is constantly forming new cells by division. By this means new vessels and wood-cells are formed. And as the new cells keep multiplying they exert pressure upon their surroundings, so that the tree gradually expands and increases in girth during the growing season. In the autumn a strong outer coat of bark is formed to enclose and protect the living cells. Dormant, yet full of life, these remain throughout the cold and wintry weather; but in the spring active life begins again. The cells commence once more to divide and multiply, and the outer coat of bark, which was firm and strong when it enclosed its living successors—for it originates from these soft, active cells—is burst asunder as the sap rushes through the cells and distends them. Thus the rough broken bark, with which we are all familiar, is formed upon the trunks of trees.

During the spring and summer seasons the growth and multiplication of the cells goes on, but pauses again in winter; and in due course, when the woodman comes along, he can approximately estimate the age of the tree by its annual rings of growth. The successive zones of growth are usually quite distinct, owing to the wood formed in the spring being less dense or having

wider cells than the compacter layer formed later in the year.

Fig. 29 shows a section of a stem with longi-

Fig. 29. Clematis has longitudinal furrows on its stem which show in this section

tudinal furrows, one of the numerous variations which the stems of plants assume. Some are flattened, others triangular; and a square stem

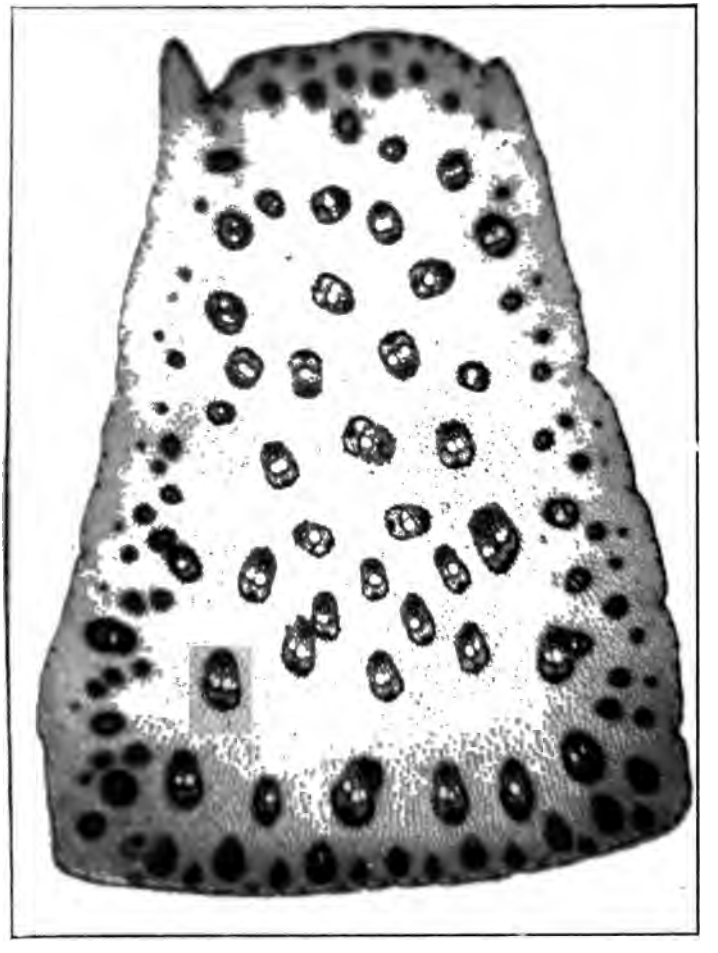

Fig. 30. Section of stem of date-palm, showing its curious form and the scattered bundles of fibrous cells

is not uncommon. Those of the red and white dead-nettle must be familiar to every one who notices wild plants at all. The stem of the date-

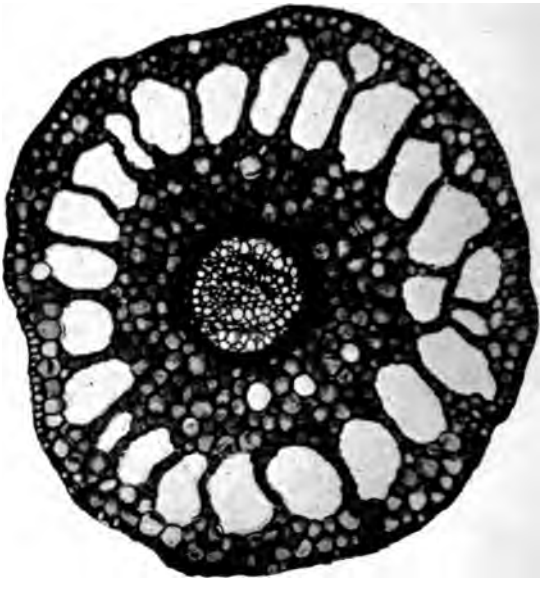

Fig. 31. A section through the stem of a water-plant, showing air cavities

palm presents another curious form in section and is illustrated at Fig. 30. This again shows the scattered vascular bundles of the monocotyledons.

In Fig. 31 is shown the section of the creeping stem of a tiny water-plant, which grows on the edges of moorlands ponds, and is called the "pill-

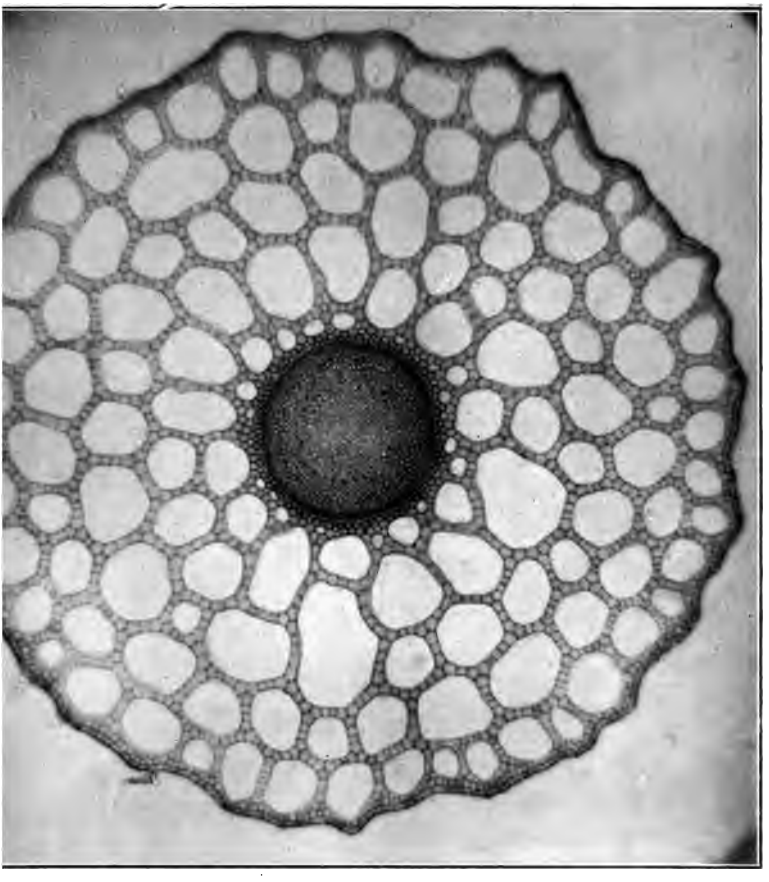

Fig. 32. Section of common marestail, showing beautiful arrangement of cells and air-cavities

wort." Here we see a ring of comparatively large, open gaps in the tissue of cells; and most aquatic plants possess these air cavities among their tissues, serving as buoys to the plant-stem.

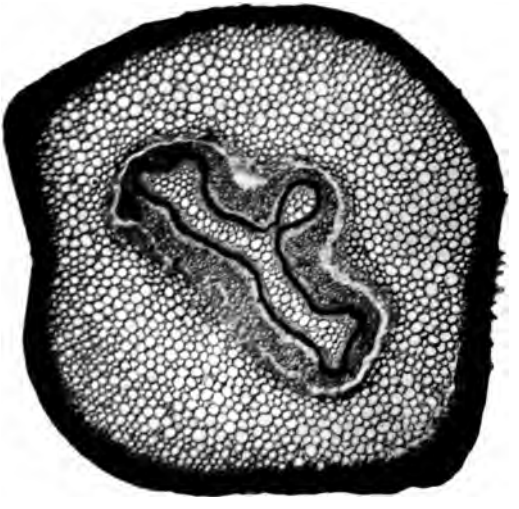

Fig. 33. The structure of a club-moss stem

The common water-lilies are familiar examples; while another beautiful example from the stem of a familiar pond and ditch plant called "marestail" is shown in Fig. 32. Perhaps lady readers might profitably use this as a pattern for fancy work, and so obtain a new design "direct from Nature."

Another curious form of stem structure is shown

in Fig. 33, taken from a plant commonly found on moorland hills and known as "club-moss." This is a tiny moss-like plant only a few inches in height at the present day ; but many geological

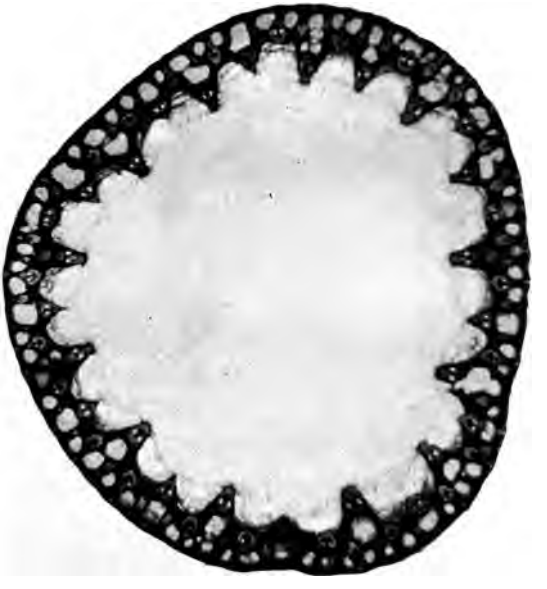

Fig. 34. The structure of a rush stem

ages ago the ancestors of our club-mosses were amongst the most prominent forms of the vegetable kingdom, bourgeoning as large trees with stems or trunks sometimes four and five feet in diameter. Fossilised trunks of these great club-mosses are often found amongst the coal measures;

and forty or more different species grew in the British Isles during the Carboniferous period; but

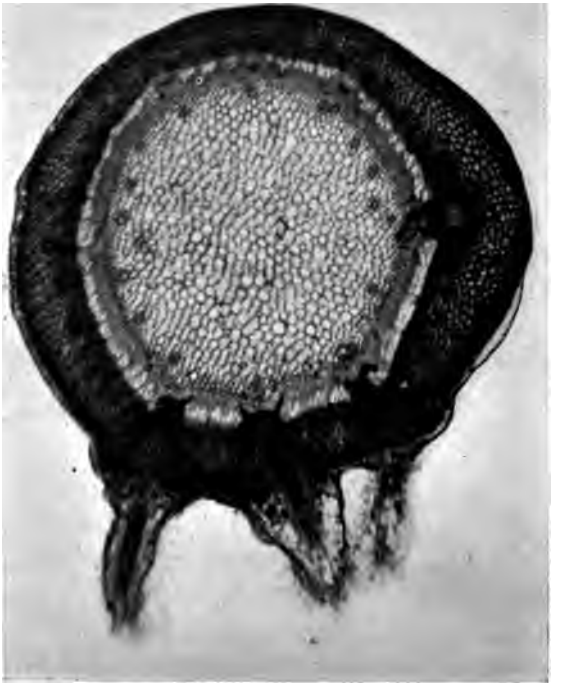

Fig. 35. Stem section of ivy, showing rootlets

to-day we have only half a dozen or so of their diminutive representatives, whose stems measure scarcely one-tenth of an inch in width.

Rushes, as every one who has gathered them

knows, have a pithy stem; and Fig. 34 shows a magnified section of a rush stem. The centre of the stem is not, however, hollow as it appears, but is filled with very unsubstantial star-shaped cells, which are too delicate for reproduction in section.

Fig. 35 represents a stem section, which seems curiously irregular in form; but when I explain that it is taken from the stem of the common ivy—which, the reader will remember, has tiny tentacles or rootlets along its stem, by means of which it adheres to walls and trees—the shape will readily explain itself.

As a concluding example of stem structure, Fig. 36 illustrates the central portion only of the stem of a liana, or tropical climbing plant, which, in some of the Brazilian forests, forms vast festoons, passing from one tree to another, and so binding together all kinds of vegetation in a maze of living network. This stem will be seen to be light in structure, probably owing to the plant's exceedingly rapid growth in the humid atmosphere of tropical forests, thus reproducing in an exaggerated form the peculiarity of the tissue formed in English trees in spring, when growth is quicker than at other seasons.

Rightly viewed, however, the stems of plants are merely enlarged and permanent developments

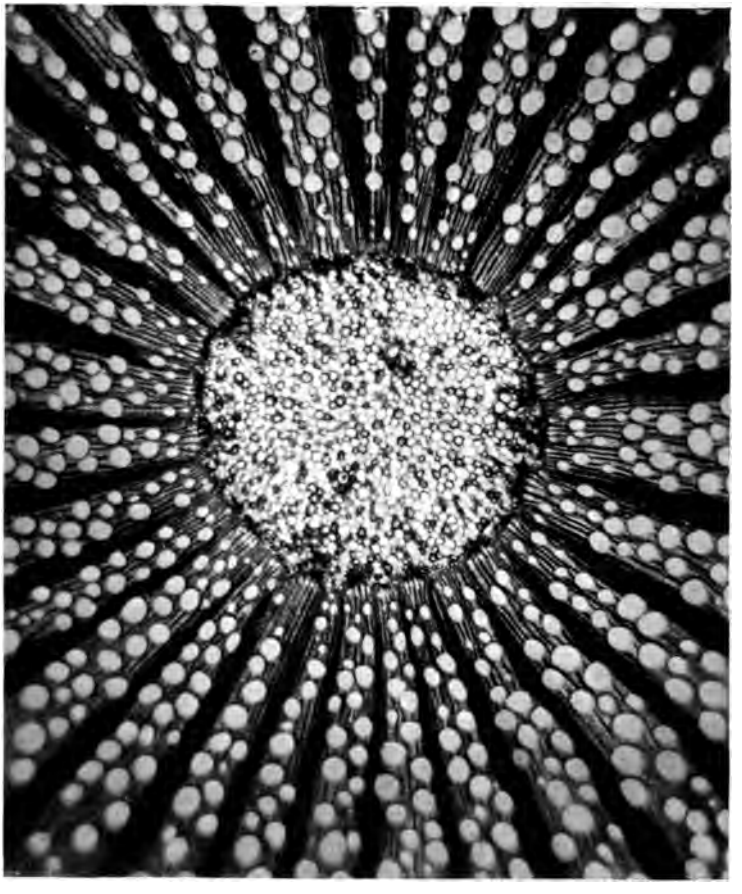

Fig. 36. Central portion of the stem structure of a Brazilian climbing plant

of a leaf stalk—there are many plants which produce only a single leaf—and the leaf stalk in turn bears the same relation to the mid-rib of the leaf. So, in Fig. 37, I show the internal structure of

Fig. 37. The structure of the mid-rib, or central vein of a rhododendron leaf

the mid-rib of the leaf of a rhododendron. There are some leaves, moreover, which apparently have no mid-rib, or are all mid-rib. It would be difficult, for instance, to say how much of the needle of a pine-tree was "blade" and how much "mid-rib" and "nerves" when viewed externally, but the microscope reveals, when the leaf is seen in section, that the vascular strands of the mid-rib

are not wholly lost but still continue their course through the central portion of these curious leaves. In Fig. 38 is shown the wonderful combination of cells which compose the pine-needle; and

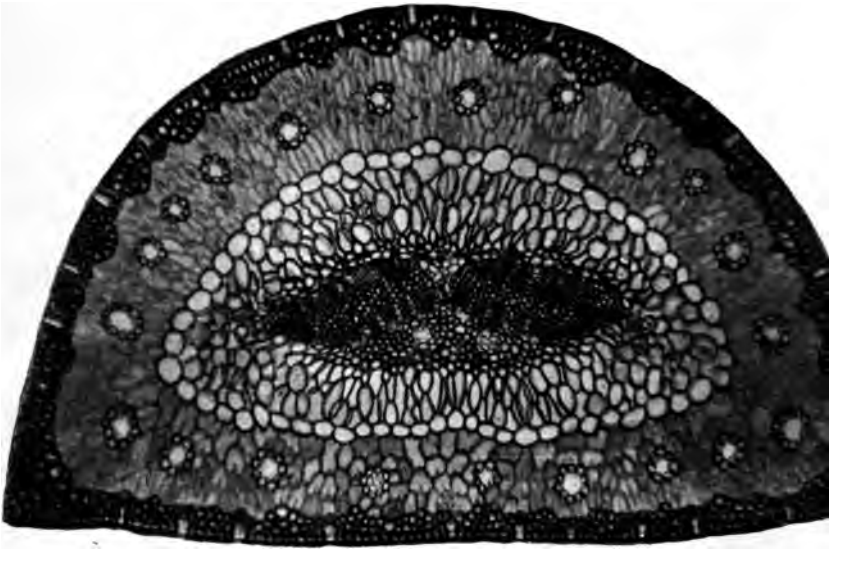

Fig. 38. The wonderful structure of the needle-like leaf of the pine. Actual diameter from corners, $\frac{1}{10}$ of an inch.

between this and the great pine-trunk, with girth greater than a man can clasp, rising sheer to the height of a church steeple, there is only the natural gradation of development. Thus, from the simple *Protococcus viridis*, which you can scrape by tens of thousands off my old garden

fence with your finger-nail, to the towering trunks of the pine-woods which furnish masts for the navy that rules the seas, there is only this difference of cells forced by compression to take some shapes and expanding with vitality into others, according to the function which Nature's necessity has decreed that they must perform.

It is not easy to make so very dry a subject as structural botany interesting. It is too full of terrifying technical terms. I am endeavouring, however, so far as possible, to avoid all "nomenclature," and I hope that this and the other chapters dealing with structural botany in this volume may not appear altogether uninteresting and unintelligible even to non-scientific readers. To the well-balanced mind, any portion of any plant, when microscopically examined, reveals the ordered pencilling of its Creator, no matter in what human terms its wonders may be expressed.

CHAPTER III

A GREEN LEAF

THERE are really no "marvels" in Nature, because everything which is has its proper place in a sequence of simple cause and effect. Yet we are so accustomed to judge things by what we can see of them with our unaided eyes that it is hard to hold back the exclamation of surprise and wonder when the microscope reveals to us unsuspected complexities in structures which we have previously regarded as simple and insignificant. Take a green leaf for example. Nine out of ten of us are satisfied to know that it is the habit of plants to be covered with green leaves, which usually fall off when the cold of winter nips them but grow again in spring. To ask why plants have leaves seems as idle a question as why birds have feathers, or fishes scales: so when, under the microscope the elaborate structure and important functions of leaves are made plain when we see that, not only the life of plants, but the life of all things that live depends

upon the activity of a certain green-coloured substance which fills one layer of tiny cells in the leaves of plants, the temptation to exclaim "Marvellous!" is great.

It is not enough, of course, merely to gaze upon the magnified structure; we must at the same time endeavour mentally to analyse a leaf and learn of what chemical elements it is chiefly composed. Having thus gained a knowledge of its structure, and of the matter of which it is principally built up, we are in a position to trace the connection of the two and the consequences of that connection.

In Fig. 39 is shown part of a magnified section of the blade of a laurel leaf, made to exhibit its internal structure. As the laurel is an evergreen, the upper surface of its leaf has a protective layer of a varnish-like substance, probably to protect the leaves from injury by the frost of winter. Immediately below this varnish layer is situated another layer of large cells, which botanists call the "epidermal tissue." These cells usually are transparent and colourless, and full of water, and serve to protect the internal tissues of the leaf from excessive evaporation and external injuries. Boys are fond of tearing a laurel leaf crookedly so that this layer of colourless cells extends like a fringe beyond the green part; then, placing the torn fragment between their two thumbs and

blowing hard, they produce horrid, squeaky noises. This, however, does not amount to scientific investigation of the structure of plants; and, resisting the temptation to make squeaky

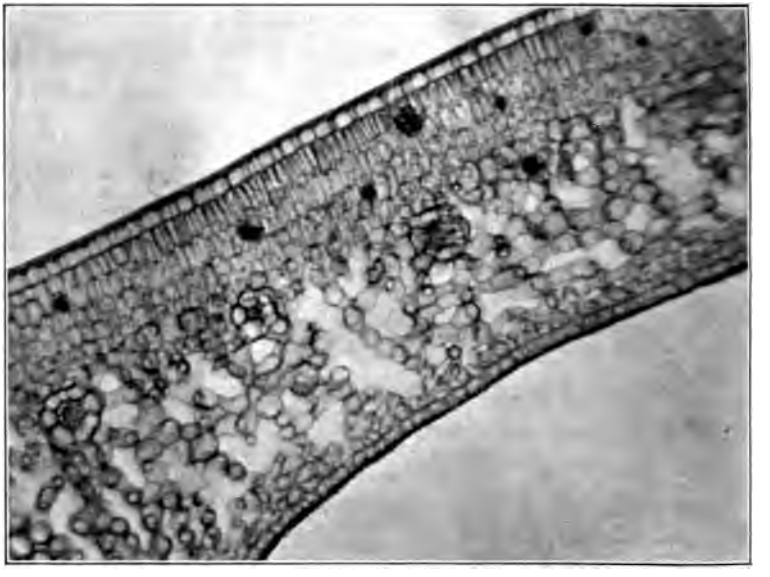

Fig. 39. Part of a section of the blade of a laurel leaf to show its internal structure

noises with the skin of the leaf, we find below it a series of regular, closely packed green cells. These give the green colour to the leaf, being seen through the transparent layer above. They are called the "palisade cells," and their green

colour is due to the presence of numerous microscopic green granules embedded in their otherwise colourless protoplasm, in the same way that our blood, which is really colourless, appears red

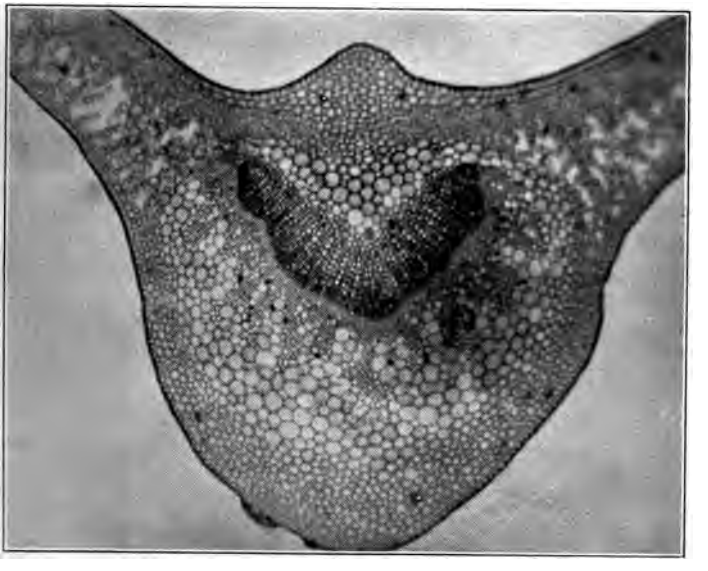

Fig. 40. The mid-rib or central vein of the laurel leaf, showing its structure

owing to the minute red corpuscles with which it is crowded. These green "chlorophyll-corpuscles" may be said to perform the most important function of any organism in the history of life, as we shall see later.

Below these palisade cells comes a kind of

spongy cellular arrangement, which serves to evaporate superfluous water, and so keeps up

Fig. 41. Part of a section through the blade of the sunflower leaf, showing many-celled hairs

the circulation. Finally, the under-surface of the leaf, consisting of another epidermal layer of

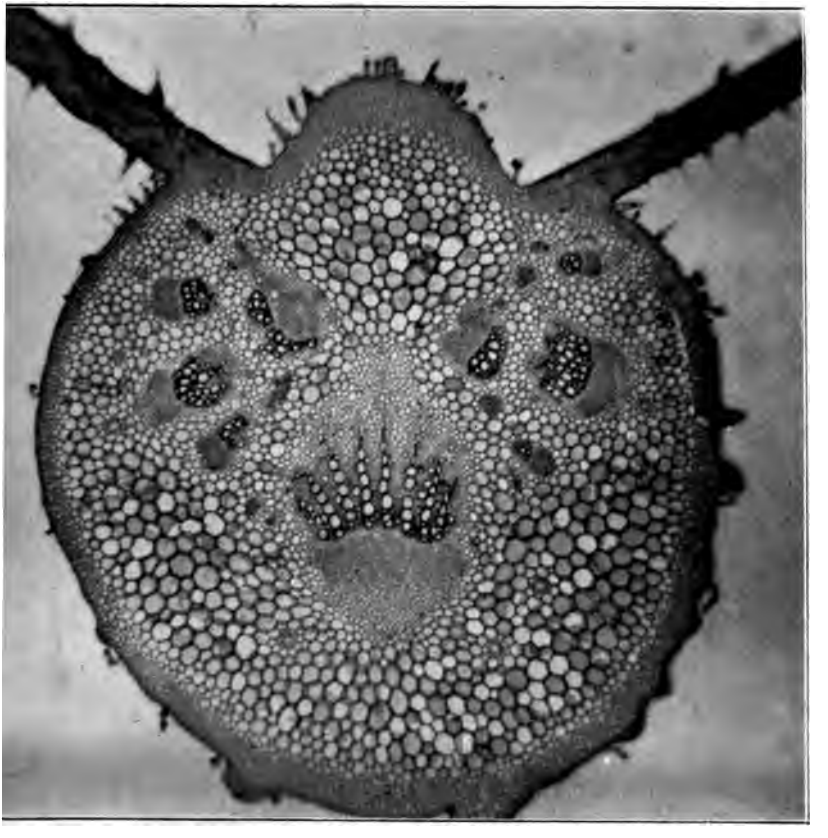

Fig. 42. The mid-rib or central vein of a sunflower leaf

transparent cells, completes the structure, as shown in the illustration—excepting only the few darker rings of cells intermixed with the palisade and spongy cells, which represent the cut ends of the nerves or leaf veins.

Fig. 40 gives the central vein or mid-rib from the same section of this leaf, showing that the mid-rib gradually assumes a structure more identical with that of the stem (a description of which was given in the previous chapter) rather than the leaf-blade. Figs. 41 and 42 illustrate sections from the blade and mid-rib of the sunflower leaf for comparison; but you will notice that the rough leaf of the sunflower differs from the smooth one of the laurel in having minute many-celled hairs arising from the epidermal tissue.

It is the continuation of the leaf-stalk or "petiole," as botanists term it, which constitutes the mid-rib, and the same structure becomes similar to the young stem as it nears it; but towards the apex of the leaf the various vascular tissues often disappear by degrees, merging their original character in the more simple cellular structure of the leaf.

If we examine the growing-point of a stem where new leaves are being formed, to trace their origin, we find at the apex (see Fig. 43) a conical

mass of small-celled tissue or "meristem," as botanists term it, the cells of which are continu-

Fig. 43. The growing point of a stem, where new leaves are being formed

ally dividing and subdividing to form new tissue, forming lateral protrusions in regular succession. Each protrusion is the basis of a leaf, and as these

increase in size, spaces form between them, until we get the stem with leaves arranged symmetrically round it at regular distances, as we see it in the branch of any familiar tree.

Of course there are many variations in leaf

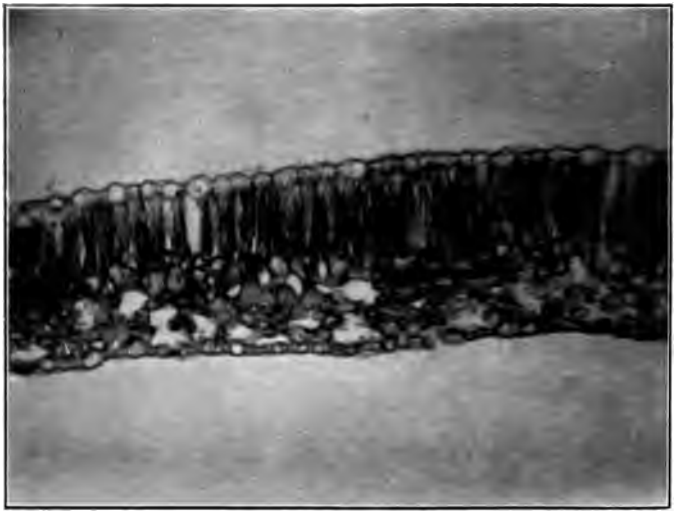

Fig. 44. Section of leaf of the deadly nightshade, showing large palisade cells

structure. For instance, Fig. 44 represents a section through the leaf of the deadly nightshade, the structure of which, on comparison with the laurel leaf section, will be seen to differ by the omission of the outer varnish layer and more conspicuously by the palisade cells occupying at least

one half of the leaf-tissue as a single layer of large cells instead of several layers, as in the case

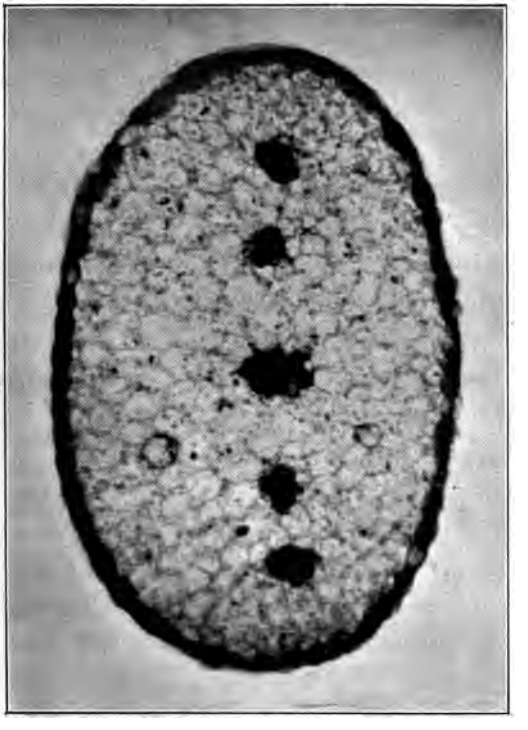

Fig. 45. The fleshy leaf of a stonecrop

of the laurel and sunflower leaves. A difference of this kind is but a minor matter. Some plants, however, have to modify their leaf-structures very much to adapt themselves to their particular

circumstances in life ; and in Fig. 45 is shown a section of the fleshy leaf of one of the stonecrops —plants which grow in dry, sandy, or stony situations, and develop thick, fleshy leaves, like short stalks in clusters, so as to retain moisture and prevent evaporation when exposed to the heat of the sun's rays. Many desert plants like cactuses, euphorbias, acacias, &c., have dispensed altogether with true leaves, their functions being fulfilled by the thick fleshy stems ; though it is sometimes perplexing to decide where leaves end and stems begin. It will be seen in the stonecrop that the epidermal structure is thickened and strong, and that the internal tissue is more or less uniform, in comparison with the previous leaf-structures.

As another example of a different form of leaf, a section of the curious awl-shaped leaf of the pine is represented in Fig. 46. The epidermis is also, in this case, thick-walled, because the pine, being an evergreen like the laurel, requires protection in winter. The mid-rib in this leaf consists of the two vascular bundles or central veins, which show distinctly in the illustration, and which are but the continuation of the leaf stalk. The straight palisade cells are in this instance replaced by others of sinuous outline, to contain the green chlorophyll grains ; while the tubes

encircled with dark cells, and situated at intervals round the margin of the section, are resin ducts

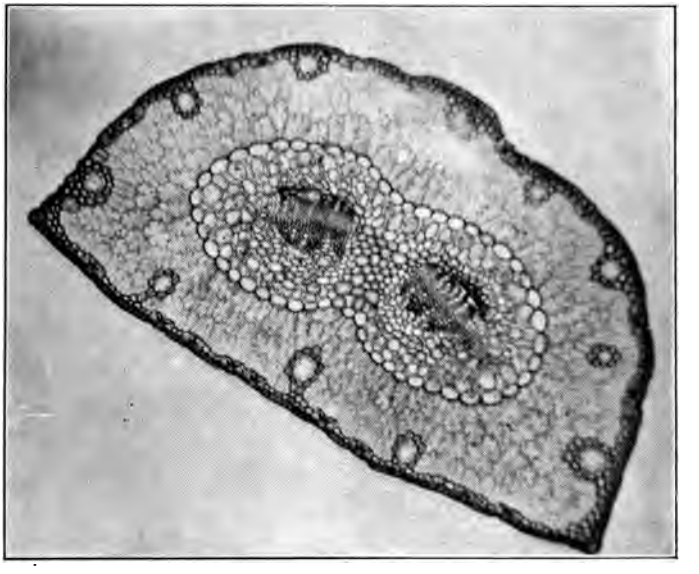

Fig. 46. The curious structure of the pine-tree leaf

similar in structure to those found in the pine-wood stem.

In plants like the water-lily, whose leaves float on the surface of the water, a special arrangement is required. The spongy portion of the leaf-cells becomes largely developed, and great air cavities, which act as buoys, make their appearance. In these air cavities curious and beautiful crystals

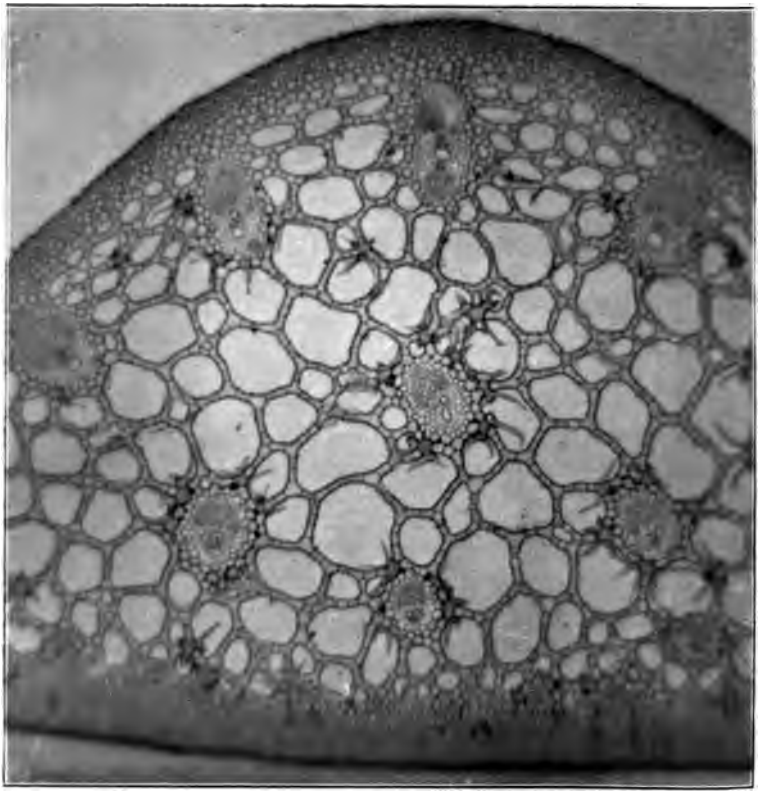

Fig. 47. The structure of a floating leaf of the water-lily, showing the air cavities which act as buoys

are sometimes formed, some of which appear in the section of the water-lily leaf shown in Fig. 47. The veins of the leaf should also be

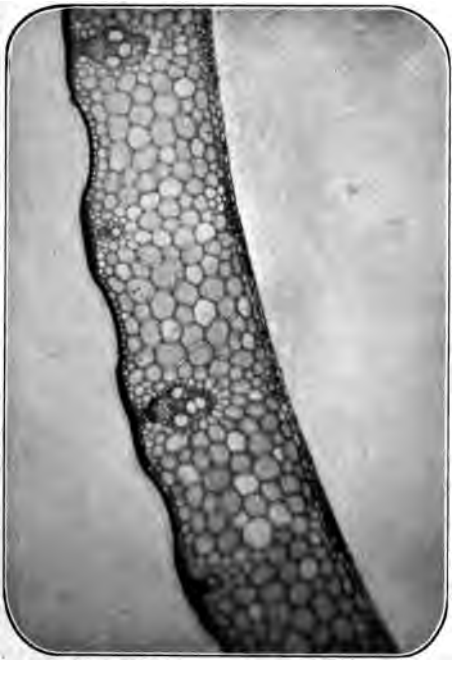

Fig. 48. The maize or Indian corn plant leaf-structure

observed, and the palisade cells which form a dense band along the upper surface.

The structure of plants which have grass-like leaves is represented in Fig. 48, this being

a section of a portion of the leaf of the maize or Indian corn, showing that the leaf-blades of plants which are widely removed from each other in the vegetable kingdom are still only variations of the same plan to fulfil the same purpose, merely specialised in the division of labour to meet the particular ends of the plant. This example may be taken as a type of the leaf structure peculiar to the "monocotyledons," the grasses, lilies, &c., in the same way that the laurel, sunflower, and water-lily were types of "dicotyledons." If we take one of the smaller plants, such as mosses, which are neither "dicotyledons," *i.e.*, plants whose seeds throw out a double leaf, nor "monocotyledons," which send out a single shoot, like a blade of grass—plants, indeed, which have no seed-leaves at all, because they have no proper seeds—we find that there is seldom need to make a section of a leaf, because the leaves of most mosses consist of a single layer only, of cells, which are generally simple as shown in Fig. 49. It will be seen that these leaves have no mid-rib, although there are some mosses in which this differentiation of tissue first begins to appear with a few thick-walled cells or rudimentary vascular strands which constitute the first step towards the evolution of the mid-rib, so highly

Fig. 49. The thin transparent leaves of a moss

developed in some of the plants which we have been considering.

Having now glanced at the structure of various types of leaves, before considering the purposes of their various cellular divisions, let us roughly analyse a green leaf and see of what elements it is mainly composed. We take a few fresh green leaves and carefully weigh them on a chemical balance so as to be exact. Having taken their precise weight, we place them in an arrangement over a lamp where they may be heated to a temperature equal to that of boiling water, and leave them there for several hours; after which we remove them and weigh again. Of course they have dried up, having parted with their moisture, and on weighing we find that they have lost about four-fifths of their original weight. So it is plain that four-fifths of their original weight was water, which has been driven off as vapour by the heat.

The leaves may now again be heated in a suitable vessel until they burst into flame. After burning, there remain only charred bits of carbon or charcoal, which may be allowed to burn on until nothing is left but a grey ash. This ash we can destroy no further by burning, as it is the indestructible mineral residuum of the leaf. After allowing it to cool, we weigh this ash and find a

very small fraction of the weight of the dried leaves remaining.

Hence we conclude that fresh leaves consist of water to the extent of about four-fifths of their substance, while the remaining fraction is largely carbon or charcoal, though they contain a small percentage of mineral matter, probably averaging from about two to seven per cent. of the whole. A certain gaseous portion has also been burned away into the atmosphere during the experiment, but we need not consider this.

This extremely small fraction, by weight, of ash, is nevertheless very important to the plant, and has been absorbed by the roots in solution, from the soil. And this is practically all that plants, generally speaking, obtain from the soil except water. Where, then, did the plant obtain its great weight of carbon from?

When we stand by a great oak-tree and admire its monstrous girth, and think of its many tons of solid substance, chiefly built up of carbon obtained from the air by the leaves during sunlight, year after year, surely we must recognise that a leaf is not the least significant of Nature's works.

The wonderful arrangements of cells that we have examined in the leaf perform this great work unceasingly, from the springtime, when they are spread out in the newly born leaf, until its fall in

the autumn. And when we speak of the "fall of the leaf" it must not be supposed that the leaves fall off by accident or because the frost has nipped them. The tree has arranged for this fall long beforehand. If we examine the scar where a leaf has recently fallen, we find that it is carefully protected by a layer of cork or bark-like cells, so that no open wound is left into the internal tissues of the plant.

Fig. 50 shows a section through the portion of a virginian creeper's stem, where a leaf-stalk joins it, just before the leaf would have fallen. It will be seen how the outer bark-like cells had severed the darker vascular bundles or veins, which go into the leaf, and had continued their protective covering between the leaf-stalk and stem, in readiness for the separation which was about to take place. Above this is seen, in section, the bud which had formed in the axil of the leaf, and which would have remained as such until the following spring, when it would have developed into a new branch of the plant.

But from the time that the leaf expands in spring until it falls in autumn or, in the case of evergreens, in the following summer, it never ceases during the hours of sunlight to accumulate carbon for the plant. It is a familiar fact to every one, almost, that our atmosphere is always be-

coming polluted by having poured into it enormous volumes of carbon dioxide, or more familiarly

Fig. 50. Section through the base of a leaf-stalk prior to its fall, showing how the bark cells separate the tissues

carbonic acid gas. Large manufacturing works may turn thirty tons or more of this impurity into the atmosphere in the course of a single day, while

every living animal is continually inhaling oxygen or pure air from the atmosphere and converting it into this carbonic acid gas.

Now, plants, in their development through unnumbered ages, have used this carbon gas just as animal-life has used oxygen. So it comes about that we make a kind of exchange, the animals supplying the plants with carbon to build up their tissues, while the plants in return supply the animals with oxygen, or the "breath of life." This is how the leaves fulfil their important functions, in the scheme of Nature.

If we chemically analyse carbon dioxide we find that it is composed of one part carbon and two parts oxygen. And if we could take one part of solid carbon and chemically combine it with two parts of gaseous oxygen, we should produce one part of this gaseous carbon dioxide.

Now, when this gas, which is always floating in the atmosphere, reaches the green leaves this is exactly what takes place. The leaves first drink in this carbon gas from the air during sunlight, after which they chemically decompose it; that is to say, they break it up into its original elements—carbon and oxygen; the carbon they retain, assimilating it for their own use; the oxygen, which is of no use to the plant, but which is so essential to animal life, is returned to the

atmosphere. But how do the leaves take in this gas? If we carefully examine the skin-tissue of plants, especially the underside of the leaves, we find intermixed with the cells numerous little

Fig. 51. Some breathing-pores of a monkey puzzle leaf

mouths or pores, arranged sometimes in rows, as in Fig. 51, which represents a portion of the epidermis of one of the leaves of the araucaria, or "monkey puzzle." These tiny mouths open into the intercellular spaces in the spongy tissue, and sometimes between the palisade cells, of the leaf. The section of the pine-leaf which was shown in Fig. 38 was cut through these tiny mouths or

openings, which can distinctly be seen around the edge of the leaf section as light-coloured slits amongst the dark external tissue. And it is by means of these mouths that the interchange of gases takes place. They open during sunlight and close during darkness; and it is estimated that there are in one square inch of the underside of a lilac leaf 160,000 mouths, where, by way of contrast, in the same space on the mistletoe leaf only 200 are found. But it must be remembered that the mistletoe is a semi-parasitic plant, and therefore does not altogether earn its own living.

Fig. 52 shows a portion of the skin tissue from the leaf of a tulip and presents a good illustration of the manner in which the epidermal cells are arranged. In the centre of each cell will be seen the nucleus or life-centre, while amongst the cells the little mouths or "stomata," as the botanist terms them, show plainly.

Through these numerous tiny mouths, then, the carbon dioxide is absorbed by the leaves, and is thence passed to the green chlorophyll corpuscles in the palisade cells for them to perform their most important function of freeing the oxygen and retaining the carbon. To these little green atoms, in fact, we are indebted for the oxygen without which life would cease to exist. But this

is not all. These same atoms supply us and every living animal, not only with pure air to breathe,

Fig. 52. The epidermal tissue of a tulip leaf, showing the "stomata" or breathing-pores and cells.

but also with every particle of food that we consume. And again, they supply us with innumerable comforts in our home life; they provide material which we utilise in the making of our

furniture and the building of our homes, as well as the planks and masts of the mighty vessels that carry us to other shores. It is estimated that there are no less than 2,590,000 square miles of woodland and forest in Canada alone. If we could travel over this great area and view the enormous wood-growth that it encloses, at the same time remembering the fact that it is built up by the apparently unimportant green leaf, we should undoubtedly be impressed with the marvels that Nature performs with her insignificant units.

After the leaves have separated the carbon, it is passed on to the internal laboratory of the plant, where it is at once manufactured into starches, sugars, oils, &c., which serve to sustain the plant, build up its structure, and perpetuate its kind. Much of it goes into temporary storehouses in the bulky substance of fruits, nuts, turnips, potatoes, marrows, &c., these, of course, being designed by the plant for its own use, but often appropriated by man.

To put the matter clearly, this green chlorophyll is the mainstay of life. It is the substance which sustains life and provides material for its regeneration and continuance. For, although we may eat animal food, the animal must originally obtain its sustenance from the vegetable world, because the animal possesses no apparatus for the manufacture

of energy-yielding starches, &c., out of the inert elements of which carbon dioxide and water are built up.

This, I think, will justify me in pointing to a green leaf as one of the most important of Nature's works, for without it neither man nor any other animal could exist.

So, on the next occasion of a ramble in the country, where the atmosphere is fresh and invigorating, let us think for the moment, as we gaze at the green verdure around, of the great functions that it performs. It has been calculated that fifty million tons of carbon dioxide are passed into the atmosphere daily. Hence it follows that fifty million tons of impure air must also be purified by the green leaves: otherwise the natural equilibrium would not be sustained, and animal life would soon realise that something was amiss. So, as we breathe the pure air into our lungs and add vigour to our systems, surely we must acquire an ever-increasing respect for the laws of Nature, which fill the world with life through the scarcely noticed agency of the insignificant "green leaf."

CHAPTER IV

POLLEN, OR FLOWER-DUST

EVERY one who has smelt a large white lily is familiar with the yellow dust which he gets upon his nose ; but not every one is aware that in this proceeding he has usurped and misconducted the function of the bee. If the man with the yellow nose would wander about the garden, smelling other lilies, he might be almost as useful as a bee or a fly ; for he would convey the male pollen-dust of one flower to the female organ of the next, and so ensure cross-fertilisation, which is so essential to the welfare of plants. Man, however, has no purpose to serve by making himself ridiculous in this way ; so he desists. But the bee, who gains a draught of nectar from each lily-bloom, goes on and on, until he has married all the full-blown lilies in the garden to each other.

For the first fact which we have to realise in order to understand the life of plants is that amongst flowers sex exists as much as among

animals, though the male and female individuals are not necessarily separate plants or even separate blossoms. Indeed, the greater number of flowers consist of both male and female indi-

Fig. 53. The central portion of a male begonia flower (slightly magnified)

viduals in one bloom. Sometimes, however, the male and female flowers are separate; and our illustrations, Figs. 53 and 54, show the central and essential organs of the two sexes of flowers of a cultivated begonia, slightly magnified. Fig. 53 represents a male flower and reveals a cluster of golden-stalked objects with swollen globular

heads, which the botanist terms "stamens." These swollen heads or, to be exact, "anthers," play a very important part in the flower's history; for it is in them that the fructifying pollen-grains

Fig. 54. The central portion of a female begonia flower (slightly magnified)

are developed and ripened, after which the anthers burst and shed their thousands of coloured granules just at a time when the showy and coloured parts of the flower, as well as the honey, are at perfection. For the main function of the coloured portions of the flower is only advertisement to insects, of good honey or nectar within. The plant has no interest in providing honey for

its insect visitors other than the transference of the pollen to the female blossoms; as likewise the insect has no friendly desire to convey these male fertilising grains to their destination, but inadvertently does so, owing to the cunning adaptation of the flower, which dusts it with pollen-grains while it is gathering the honey.

The second illustration (Fig. 54) exhibits a striking difference, although it represents a flower from the same plant, for this is the sister blossom. Instead of the crowded pollen-bags we see several fringed corkscrew-like objects, which collectively the botanist terms the "stigma," and these represent the receptive surface for the pollen-grains which are rubbed from the legs and bodies of the winged insects that have previously visited male flowers. This, then, constitutes the transference of the pollen by insects, and is sometimes called "fertilisation," although it is merely the means to that end. Fertilisation has yet to take place, but of this more anon.

As has been said, however, all flowers will not be found, like our begonia, to have separate sexual flowers. If a buttercup, primrose, or fuchsia-blossom be examined, each will be found to contain both pollen-producing stamens and receptive stigma; hence these are male and female flowers combined. But plants like the begonia,

with separate sexual blossoms, are almost certain to have all their female flowers fertilised by pollen from neighbour flowers, and so a measure of cross-fertilisation is brought about, which results in

Fig. 55. Stamens from various flowers, showing pollen-sacs or anthers (slightly magnified)

better seed than those produced by pollen from the same flower.

Now that we have seen what a stamen is, we may look into a few flowers for them, and we shall notice at once that, while some have no stalks, but consist of anthers or pollen-sacs only, the greater number are stalked and often conspicuous. A few of these are shown slightly magnified in Fig. 55, the first being that of the fuchsia, with white pollen-grains bursting from

its anther; and the second, that of an African lily, with dark grey pollen. The stamens of the lily tribe are conspicuous by their movable or "versatile" anthers, and are familiar in the large white and tiger lilies, a stamen from the former being shown as the third example in the illustration. The fourth represents the stamen of the garden nasturtium; the fifth, that of a snapdragon, with bright yellow pollen; the sixth, a begonia, with paler yellow pollen; and the seventh, an unripe stamen of the foxglove, with its pretty divided yellow anther spotted with red. After ripening this eventually bursts and scatters myriads of silvery pollen-grains. Thus it will be seen that the pollen-grains vary greatly in colour in different flowers, although yellow is strongly dominant.

The stamens and anthers in highly developed types of flowers are usually so arranged as to ensure fertilisation by means of the insects which visit them; but I have space for only one example to illustrate this. Fig. 56 shows the inside of a blossom of the foxglove, which has been cut open, showing its stamens and stigma *in situ*. The corolla-tube of the foxglove is neatly adapted to the bulk of the large humble bee, and as it enters and backs out again, with this arrangement of ripe anthers over its back, it

invariably gets dusted over with the abundant pollen, and this it carries to the next flower,

Fig. 56. The tubular corolla of the foxglove opened to show the stamens *in situ* (slightly magnified)

where the stigma is ripe and receptive. For the honey or nectar which it seeks ripens together with the anthers and stigma, the insect, therefore,

passes over those flowers whose nectar is sour and unripe, just as we should unripe fruit, and so it becomes almost impossible for the bee to enter and return without leaving numerous fertilising pollen-grains.

But it may occur to the reader that the bee would rub or shake the pollen from the stamens on to the stigma of the same flower. This, however, is prevented by the simple arrangement of the anthers coming to maturity and scattering their pollen before the stigma becomes receptive, after which the stigma develops and ripens and so receives pollen from other flowers. The stigma in the illustration can just be seen peeping above the upper pair of anthers, and the latter are shown just when the anthers are ready to burst. It may seem somewhat astonishing that such vast quantities of pollen should be produced; yet, considering the great amounts that are washed away by heavy rains and damaged from other external causes, not to mention the quantities that are appropriated by bees to make "bee-bread" for their young, this abundance only reveals Nature's adaptability to circumstances.

To examine pollen by means of the microscope with suitable illumination invariably causes astonishment and delight, for these tiny granules then appear in their natural colours and extra-

Fig. 57. Pollen-grains falling from the stamens of one of the mallow flowers (magnified)

ordinary forms, often like clusters of jewels both wonderful and beautiful. Fig. 57 shows a few stamens from a flower of the mallow family with the pollen-grains falling from them. Each grain,

it will be seen, bears an individuality, is in fact a perfect little translucent sphere; but this is not all, for, when highly magnified, each is studded over with regular spiny projections after the

Fig. 58. Spiny pollen-grains of the hollyhock

manner of the hollyhock pollen-grains shown in Fig. 58. As the mallow family present very fine examples of stamens and pollen, I have given a further example of a cluster of ripe stamens from a common mallow in Fig. 59.

The curious external markings, spines, sculpturings, and roughened surfaces, and the geometrical forms assumed by the various kinds of pollen, not only provide beautiful objects for

Fig. 59. A cluster of ripe stamens of a common mallow flower, showing pollen-grains (magnified)

microscopic investigation, but are also of service in more readily adhering to the hairy legs and

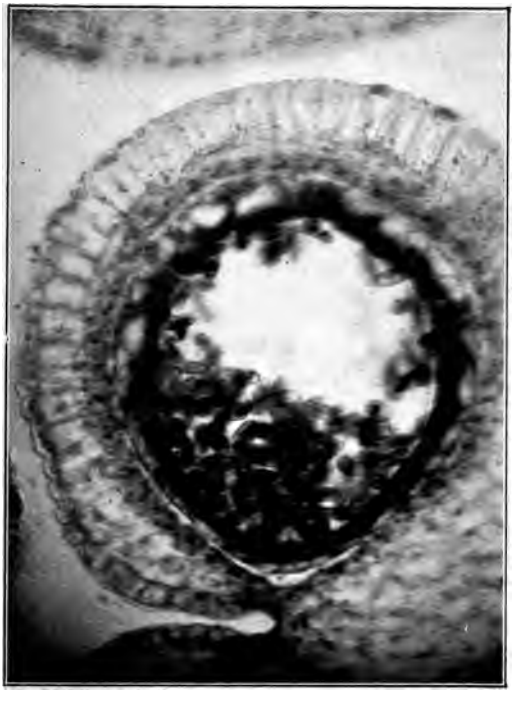

Fig. 60. Section of the anther or pollen-sac of a lily, showing pollen-grains within

bodies of insects, as well as to the sticky stigma to which they are subsequently transferred.

If we make a section through an unripe anther-sac, such as is shown in Fig. 60, we find the

pollen-grains dividing up amongst themselves as the plant growth proceeds to form new grains, until the sac bursts with its store of ripe fertilising

Fig. 61. The compound pollen-grains of Catalpa

dust. And this brings us to the pollen-grain itself, for these tiny and beautiful vegetable atoms exist, generally speaking, as individual cells, complete

in themselves after they leave the ripe anthers, although exceptions often occur. For example, Fig. 61 shows an instance of compound pollen-grains, though even these are really composed each of four individual grains externally united. Similar compound grains are found in some orchids, while in others the whole of the pollen-grains remain united into two club-shaped masses, which become attached like two horns to the head of the bee as it visits the flower, and so are carried whole to the sticky stigma of the next blossom it visits.

To understand the structure of the pollen-grain we must make a section of it. This may seem an extraordinary suggestion, considering that we are dealing with a microscopic atom to commence with. However, Fig. 62 shows several sections of pollen-grains highly magnified. In these examples it will be plainly seen that each grain is surrounded by a cell-wall, the outer surface of which bears the raised points, ridges, and other markings found on the pollen-grain. Even this simple-looking cell-wall is found to consist of at least two different layers of vegetable tissue when seen still more highly magnified.

Inside these protective layers is a dense mass of granular life-matter, or "protoplasm," which is rich with starch grains and tiny drops of oil, and

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amongst which the nuclei or living centres of the grains exist. Of the layers of tissue which constitute the cell-wall of each grain, the botanist

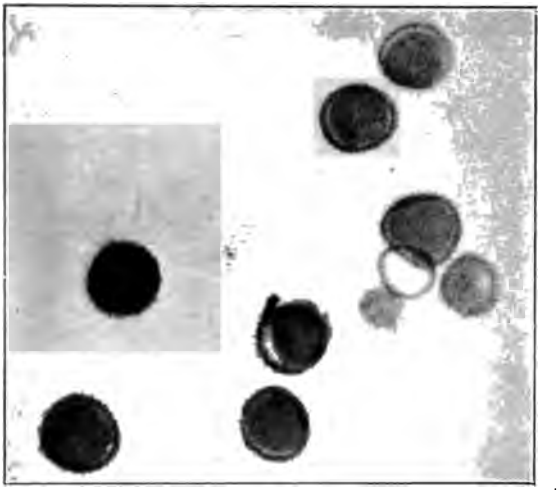

Fig. 62. Sections of pollen-grains of the mallow flower, showing that the microscopic granules possess the characteristics of vegetable cells

terms the outer layer the "extine," and the inner the "intine." When a pollen-grain reaches the stigma the viscid fluid which the latter secretes causes a kind of germination to take place, and through certain weak places in the extine layer the intine begins to bulge and gradually forces a way through, assuming the form of a little tube, which increases in length in a very wonderful way,

acting very much like the young root of a germinating seed as it penetrates the soil, the difference being that, instead of growing down into the soil, it penetrates the stigma and continues its course through the spongy tissue until it reaches the ovary or seed vessel, guided by various contrivances such as delicate hairs or papillæ. The pollen-tube, formed from the elastic tissue of the intine, reaches an extraordinary length in comparison with the size of the grain before it reaches the ovules, which after fertilisation are destined to become fruitful seeds. Here the pollen-tube opens, and the contents of the pollen-grain, including a nucleus, are passed through the tube into the embryo seed, after which the seed develops by a natural growth.

Fig. 63 shows a section of a portion of the stigma of the evening primrose, with the germinating pollen-grains in position. These pollen-grains are flattened and of triangular form, some of them being shown in Fig. 64, and it will be seen in the former example that the grains emit their tubes at the corners, and these can readily be seen insinuated amongst the cells of the stigma and its neighbouring tissues.

In Fig. 65 is shown another example of a flat triangular form of pollen-grain from a common garden *Godetia*, which belongs to the same family

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group as the evening primrose. Indeed, it is, generally speaking, an easy matter for the botanist

Fig. 63. A portion of the stigma of the evening primrose shown in section with the pollen-grains emitting pollen-tubes which penetrate the tissues of the stigma and ovary

to trace the family to which a plant belongs by examination of the pollen-dust alone; for the grains usually possess characteristic features,

although some families develop two or three well-marked types. Fig. 66 shows a pretty pollen-

Fig. 64. Pollen-dust from the evening primrose shown in various positions

grain from the flower of *Cobæa scandens*, a cultivated climbing plant, called in its native country the "violet ivy," and allied to the phloxes of our

... The family of plants to which the dead-... ne. and similar plants

Fig. 66. The triangular pollen-grains of *Godetia*

belong are characterised by elliptic pollen-grains with three, four, or six bands or ridges arranged regularly along the length. Fig. 67 shows some interesting grains, from a cultivated plant of this

family called by gardeners *Monarda*, which possess the characteristic ridges, in this instance six in number.

The common vegetable-marrow flower of the kitchen garden produces comparatively large

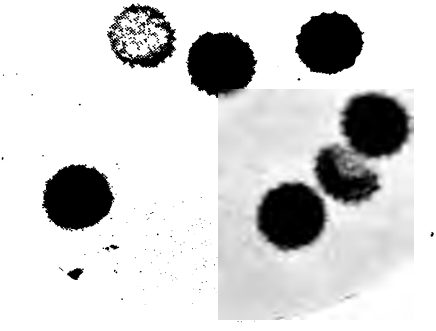

Fig. 66. Pollen-grains with the surface reticulated in a regular hexagonal manner

spherical pollen-grains, shown in Fig. 68, with eight to twelve conspicuous pores each closed with a valve. The extine is studded with tiny spines, and when the intine makes its egress in the form of a pollen-tube it pushes through one of the pores, throwing its closing valve to either side, or removing it altogether: and even this valve will often have several spines on its surface.

And here let us not fail to remember that we

are considering but a microscopic grain of dust barely visible to the keenest eye. It is so easy, when engrossed in microscopic subjects, to forget how infinitely small is the original before us.

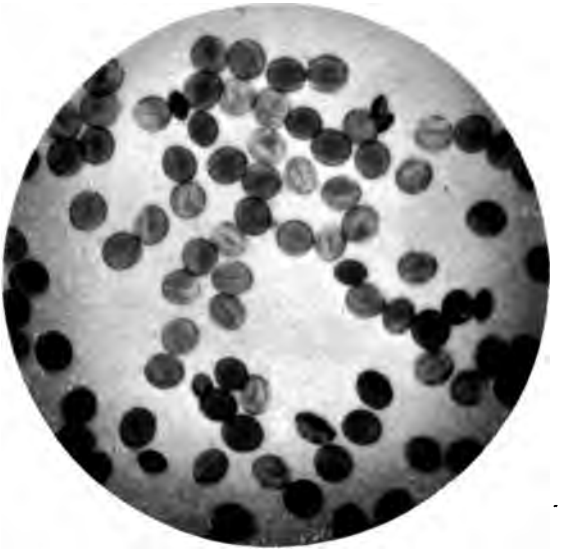

Fig. 67. Pollen grains of *Monarda*, showing the characteristic ridges of the *Labiate* order

Each of these wonderful and beautiful granules we find perfect in structure and habits, given favourable conditions, and yet the abundant quantity that is produced is quite astounding. It has been estimated that a single flower-head of dandelion produces on an average no less than

243,000 pollen-grains, each alike beautifully sculptured and formed. And again, in the case of a pæony, 3,654,000 grains have been recorded, and as an average for the blossoms of a single rhododendron bush no fewer than 72,620,000 grains

Fig. 68. Spherical pollen-grains of the vegetable-marrow flower, showing pores

have been estimated. And, since these numbers apply to flowers fertilised by insects, the enormous totals that would be reached by wind-fertilised plants such as pines, firs, birches, poplars, grasses, &c., are beyond our calculation or even imagination. These wind-fertilised flowers are usually

developed in the spring before the leaves, so that the latter are no obstacle to the pollen, which is blown in showers from tree to tree, and showers of pine-pollen are frequently recorded at con-

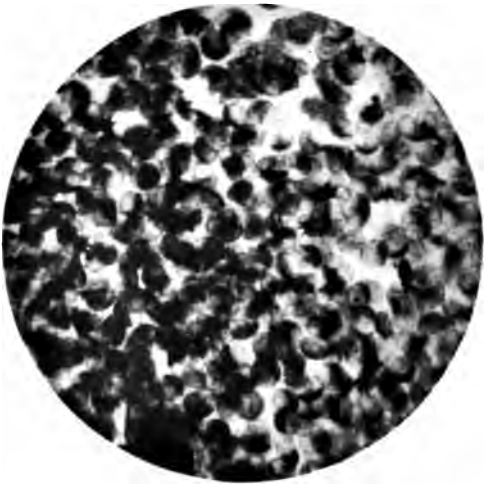

Fig. 69. A magnified view of the familiar dust or pollen of the pine-tree flower

siderable distances from the source of their origin. Sometimes the pollen from remote woods has fallen in the streets of towns, giving the surface of the puddles a sulphur hue, and so has caused alarm to the inhabitants, who imagined a fall of sulphur had really taken place, and conceived fears of worse things to follow, until the microscope plainly revealed the true nature of the supposed portent.

Fig. 69 shows some crowded grains of the pollen of the pine, which in shape are somewhat like a curved dumb-bell.

This has necessarily been a brief and cursory account of the pollen-grain and its functions ; but it may at least have served some purpose, if it has again brought home to some readers the fact that beauties of form exist, and marvels of function are carried on, beyond the range of unaided human vision. It should teach man humility to reflect that, although he sees nothing of these fascinating wonders, they lose nothing thereby. His is the loss.

CHAPTER V

ANIMAL-PLANTS AND SEA-WEEDS

PEEKING amongst the rocks and rock-pools in search of "the flowers of the sea," one catches glimpses of wonderland. In great waving masses the larger sea-weeds fling out their long coloured tresses to be caressed and carried by the waves; for these "algæ," as science calls them, have no strong branches to support their own weight. If they had, they would be broken and tattered after each storm; but, bending and twisting with the waves, perfect in every movement, they are beautiful and as safe as may be in so dangerous an environment. After a gale we find them uprooted rather than broken. Their beauty is marred and draggled on the sand, but, if we take some of these apparently shapeless tangles of slimy stuff from high-water mark and place them in the nearest pool, in an instant their fairy beauty has returned, and they are once again gracefully waving to and fro.

But these large fronds will not monopolise the

interests of those who study the sea-shore in search of Nature-marvels. These are often best seen in her most insignificant and apparently unimportant works. To illustrate this, I have collected almost at random a few tiny specimens of what would popularly be considered as "sea-weeds," if they were considered at all; for all of them would find abundant room in a thimble.

But there are often many so-called "sea-weeds" gathered from the sea-shore by the unscientific and given a place as ornaments in vases, which are really not sea-weeds at all. Fig. 70 exhibits a "sea-weed" arrangement of this kind; although, as a matter of fact, none of its constituents even belong to the Vegetable Kingdom, but are placed by modern biologists with the animals. My thimbleful of specimens contains many of these animal-plants, for it is seldom that you can gather algæ or sea-weeds without finding some of these curious living growths attached. Nor is it only adhering to the fronds of algæ that we find them, for it may be from an oyster, or any other shell, or a bit of wood or stone, that the primary bud commenced to branch.

These plant-like forms, of symmetrical and graceful outline, mimic in general appearance many of the sea-weeds amongst which they live, and may readily be mistaken for them; but, if we

Fig. 70. An arrangement of animal-plants, which look like sea-weeds (natural size)

examine some of their structures and learn something of the strange organisms that build and inhabit them, we shall see how unlike plants they really are. Fig. 71 shows a small portion of a few branches taken from one of those animal-

Fig. 71. The branches of an animal-plant or zoophyte (magnified slightly)

plants slightly magnified. It is branched like a plant, but if its thread-like branches are examined they are seen to be notched. Moreover, these notches are found to have cellular orifices at their points forming tubular openings into the interior of the main stem. These openings, as will be seen, occur along each side of the branch; and each orifice is tenanted by a tiny living animal. Here, then, we have a colony of animals; hundreds of little

cells, each forming the dwelling-place of a living inhabitant, which is called a "polype." Figs. 72

Fig. 72. An animal-plant which has beautiful coralline branches. The actual size is shown in the square to the left

and 73 show other dwelling-houses of the polypes. The former of these has, like our first specimen, tiny tubular cells arranged on opposite sides of

the branches, but, instead of being membranous in texture, the branches are constructed of an exceedingly beautiful ivory coralline substance. The example in Fig. 73 reverts again to the mem-

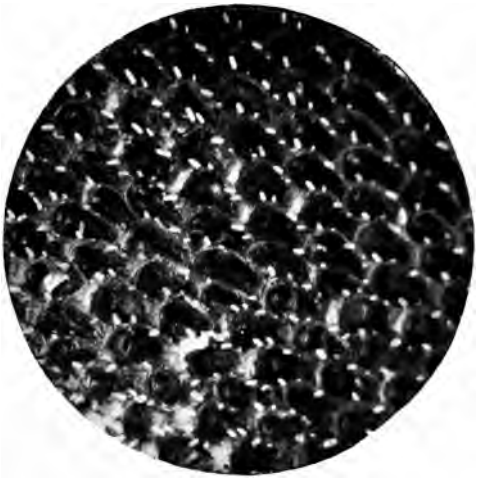

Fig. 73. Animal-plant cells arranged after the manner of a leaf, instead of branches

branous structure, but with an entirely different cellular arrangement. Instead of forming branches, a leaf or frond-like arrangement is assumed. The cells are packed and crowded together on each side of the leafy organisms, which are familiar to seaside visitors as "sea-mats." Specimens of the natural size were the broader fronds in Fig. 70, the branch-like and finer kinds being similar to that

shown slightly magnified in Fig. 71. Wonderful habitations are these, and built entirely by their tiny inhabitants.

Remains of similar organisms are found in some

Fig. 74. Fossil zoophytes from Norfolk

of the oldest rock formations, giving abundant proof that the type flourished in the remote past. Fossil species are unearthed from every corner of our country, the rocks remaining as the record of their existence; and in Fig. 74 you may see a small group of them from

Norfolk, moderately magnified. These zoophytes, or "animal-plants," abounded in the primitive seas, fulfilling the same functions as the many living zoophytes of to-day: separating the carbonate of lime from the waters, to build habitations for themselves; and at the same time, by their myriads of accumulating skeletons during countless ages, unconsciously raising materials which afterwards would be quarried as solid rock for the dwelling-places of man himself.

As is well known, our limestones were built up chiefly by various tiny living organisms which possessed this power of separating the lime from the waters. Fig. 75 illustrates the structure of a minute portion of a very thin slice of limestone, showing how it is built up of what were once living animals. In this particular specimen zoophytes are not prominent; but each limestone varies according to the locality and period in which it had its origin.

It is easier to understand how masses of rock substance may be built up by the united efforts of minute zoophytes, after examining one of those Mediterranean corals that now constitute quite an article of commerce; the harvesting of which affords employment to some thousands of seamen and a large number of vessels especially fitted out for the gathering of these beautiful works of

Nature. For the tenants of these fantastic abodes are but other kinds of zoophytes, which hold an

Fig. 75. A very thin and minute portion of limestone, showing how it is built up of tiny living forms

intermediate place between our own tiny British species and those organisms which have built up thousands of "coral-reef" islands in the Pacific Ocean, extending in some instances hundreds of

miles. Such are the mighty works of these little artificers of the deep.

While we have been considering the habitations of these marine wonders we have seen nothing of

Fig. 76. An animal-plant feeding, by catching particles from the surrounding water with its tentacles. Actual size shown in little square

the living organisms themselves. Those who have never seen these minute marvels will naturally be wondering what these little workers of great things are like. In Fig. 76 are shown a few cups of the branch of another form of zoophyte, with its polypes busy seeking food. And if we carefully watch these in their living state, we soon observe that any particle of living matter that may

come within reach of one of their spread tentacles is greedily drawn in, the other tentacles are soon clasped around it, and it is quickly engulfed and disappears into the polype's mouth, which the tentacles surround.

To all appearances they are just little starry blossoms, almost like the flowers of the apparent plant that bears them. Yet they are little animals which greedily gather and devour other living creatures to support their own substance, and build the structures in which they dwell. Such is the general arrangement of all zoophytes; but each family varies in its habits and forms. As will be seen by the illustration, the resemblance of this animal-structure to a plant is carried to the length that each new polype appears first like a bud.

Still again, like a plant producing seed, certain receptacles are developed which contain minute eggs (see Fig. 71), and, when ripe, open at their apex by a tiny lid, discharging their contents into the surrounding water, as a plant-capsule scatters its seeds in the air. But here the resemblance ceases; for, unlike a seed, each egg at this stage is endowed with locomotion, and swims gaily about for a time, afterwards settling down upon a shell or seaweed-frond, where it commences life as an independent zoophyte on its own account, first

becoming a single polype, and then producing buds, from which each newly formed polype again buds. So in due course the parent stem grows and branches, until we get the structures that we have been considering.

We are here dealing with the zoophytes collectively without regard for their relationship to each other in modern zoological classification, although some of those which we have noticed are much more highly organised than others. And, before leaving the corals, I may notice that the hard red coral of necklaces, and the "coral and bells" of teething infants, are but the work of other zoophytes, from the depths of the Mediterranean. When brought up from the bottom of the sea this hard stem is incrusted with just a film of living matter. The slightest rough handling will remove it; yet the solid red coral was entirely formed by this incrusting film, which consists of soft jelly-like polypes. If we examine the hard core in section, we see plainly that it was once a slender rod gradually increased in thickness by additional layers secreted by the tiny inhabitants of its outer surface. For the sake of the beauty alone of their work these small living wonders are well worthy of our consideration; and, in addition, there is the legacy of usefulness left by their ancestors. Much of the beauty of our native

marbles is due to the remains of extinct zoophytes; and fossil corals add to the artistic beauty of other rock structures by their marvellous effects when

Fig. 77. Section of rock showing fossil corals

crystallised with other substances. A section of coralline rock is illustrated in Fig. 77, but no photograph can display its beauty of tints. How

seldom, too, we think of the important part which these lime-extracting organisms play in regard to the magnificent edifices which we consider as "built" by man, whereas all that man has done is to utilise and arrange the material already built by these insignificant living atoms of the past.

We have seen how these little animals seem to mimic plant structures. We have seen them bud, branch, and on occasion bear flowers, and also later produce vessels, which appeared to contain seed. So we need not wonder at sea-side visitors bringing home these animal-plants in mistake for sea-weeds, with so many striking resemblances to mislead them.

But now we will endeavour to examine a few sea-weeds or algæ, and see in detail how far the resemblance really goes.

The first thing that we have to observe is that the smaller algæ are not so hard in texture as the zoophytes, but are more delicate, many being so transparent that their internal structure can be readily examined. Fig. 78 shows a portion of a few branches from a species belonging to a family of algæ which probably will be the first weeds to attract the eye of the sea-side visitor. Their thin red and pink, thread-like, jointed branches, with repeated forkings, and tips always forked, will serve to identify them.

It will be seen that here there are no cellular arrangements for polypes, but, instead, a pretty

Fig. 78. A portion of the branches of a tiny sea-weed

formation of vegetable cells, their rosy-red joints alternating with the transparent cells of the threadlike stem.

So the branches of a true sea-weed are altogether unlike those of the zoophyt· s, though in

Fig. 79. A tiny sea-weed scattering its spores, or seeds, into the water

structural details they may differ between themselves even more than do the zoophytes. In Fig. 79 a nearly related form is given, but in this instance bearing fruit. A kind of capsule or berry containing the spores or seeds is developed amongst the branches; and some of these may be seen in various stages of development,

Fig. 80. The tip of the frond of another delicate sea-weed.
Actual size shown to the left

including some just scattering their spores into the surrounding waters.

To show how beautifully varied are the struc-

Fig. 81. Another kind of sea-weed discharging its capsule of spores into the sea-water

tures of these tiny plants of the deep, I have shown the tip of a frond of a still more elegant form in Fig. 80. This also shows reproductive

spore-cases amongst its frondlets. And then again, at Fig. 81, we have a wonderful photograph of a capsule of another species just discharging its crimson spores from its capsule. This calls to mind the urn-like vessels of the zoophytes which we have previously examined. But the resemblance is only superficial, for it is seen that the structure of the branches is not adapted for the little wonder-working polypes.

Now, perchance, some readers of this volume may, on their holiday visit to the sea-shore, endeavour to seek some of these marvels of beauty and minuteness that we have been considering. In that case some very common forms would come at once under their notice, perhaps testing their ingenuity to discover whether they were animal-plants or true sea-weeds. The reason for this would be that they possess characteristic features of both. Here, for instance, in Fig. 82 we have the beautiful white stony and coralline appearance of some of the zoophytes; but, on the other hand, there are no orifices for the polypes. The illustration shows a greatly magnified and also a natural-size representation of a portion of the frond. Clusters of these little fronds, an inch or so in length, form tufted masses of stony foliage, and line the rocks, or often, like our zoophytes, grow on old limpet or other shells. But if we

Fig. 82. Part of a frond of a curious sea-weed that develops hard and stony foliage. Shown at actual size to the left

observe carefully we notice that these are true sea-weeds, and not animal-plants. Some, instead of being snowy white, are pink or purple in colour; and these are generally living plants. When they are thrown up on the beach by a gale, to such a height that the waves cannot again reach them to carry them back into the water, the sun scorches their tissue, and they become beautifully bleached, thus acquiring the chalky appearance that gives them a resemblance to coral. But what does this mean? True algæ with hard and stony-jointed fronds? Well, the fact is simply that we have here a sea-weed which has acquired the same power as our zoophytes possessed, of separating the carbonate of lime from the water. This it deposits equally over its vegetable tissues, and so presents the chalky-white foliage we have observed. Fig. 83 shows a more delicate lime-building weed, which is found in clusters, resembling white moss, among the shingle of our beaches.

It is a remarkable feature of these lowly vegetables, that they should possess this strange power of making lime incrustations from their natural element the water, in the same way as the animal forms which we have been considering. But it is a characteristic common to innumerable forms of low life which we have no space here to consider.

The geological history of the coralline algæ goes back into remote ages, like that of the

Fig. 83. Another more delicate species with stony branches. Actual size shown to the left

zoophytes; and, like them, these families of lime-incrusting weeds have contributed largely to our

limestone strata. With the true corals also, they occur in particular abundance, and often form a

Fig. 84. A stony sea-weed and its companion stone-masons. Actual size shown to the left

sort of mortar which holds the reef-building corals together. This community of employment between animals and plants is illustrated in

Fig. 84, where a small fragment of the same stony sea-weed as appeared in Fig. 82 is given: but in this instance the sea-weed is not alone in fulfilling the building functions assigned to it by Nature. It is accompanied—perhaps more or less interrupted—in its task by other organisms, which are diligently working for the same end. On the lower joints of the frond stem will be seen a rough incrustation, which is formed of the cellular tubes of a form of zoophyte, while above these are a number of other minute animal organisms, that require similar materials to build up their own dwelling-places.

Each wrought alone, yet altogether wrought
Unconscious, not unworthy instruments
By which a hand invisible was rearing
A new creation in the secret deep.
Omnipotence wrought in them, with them, by them;
Hence what Omnipotence alone could do
Worms did. I saw the living pile ascend,
The mausoleum of its architects,
Still dying upwards as their labours closed.
Slime the material, but the slime was turned
To adamant by their petrific touch;
Frail were their frames, ephemeral their lives,
Their masonry imperishable.

J. MONTGOMERY.

CHAPTER VI

INSECTS' EGGS

THE extraordinary variety of artistic forms, exquisitely sculptured surfaces, iridescent colours and colour markings, exhibited by the tiny eggs of almost all insects, offer to the observer with the microscope a fascinating field. Apart from the æsthetic pleasure derived from the study of these beautiful things, a great deal of general knowledge of the insects themselves is gained. It is even possible to classify butterflies correctly by their eggs.

And the endeavours of naturalists to identify the eggs of insects by observing where and how they are deposited, and by watching their subsequent development, have resulted in abundant knowledge concerning the lives of insects, in place of the superstitious theories and fanciful reasonings of less than a century ago.

No longer are maggots, flies, and swarms of bees supposed to be spontaneously generated from putrefying substances. Nor could any man

of modern science now say: "That the atmosphere is freighted with myriads of insects' eggs that elude our senses, and that such eggs, when they meet with a proper bed, are hatched in a few hours into a perfect form, is clear to any one who has attended to the rapid and wonderful effects of what in common language is called a 'blight' upon plantations and gardens;" or assert that, the honey-dew which is produced by the aphides "is a peculiar haze or mist loaded with poisonous miasm." Yet both of these statements were gravely put forward by an eminent naturalist in 1829, in connection with the common, but unpleasant, phenomenon of the sudden appearance of small life in vast numbers where, from man's point of view, it was not wanted. Such errors are impossible now, and one needs not much science to be aware that the mother blue-bottle or "blow-fly," scents the meat afar off, and with maternal instinct hastens to lay her eggs upon it that her young may thrive, the young grubs appearing more or less rapidly according to the temperature.

The common house-fly in like manner usually discovers material in which her young may undergo their metamorphoses; and sometimes she selects such substances as ripe fruit, sweet cakes, or even bread, as a suitable situation for her curious white

or cream-coloured eggs, winged, and honeycombed with minute hexagonal pits (see Fig. 85). In

Fig. 85. The eggs of the common house-fly. × 25 diameters

warm weather these remain about a day before hatching, and are just visible to the eye as tiny white specks; but it is to be feared that the

average man consumes more of these "interesting objects" than he observes.

Insects' eggs vary greatly in number. Some insects deposit, perhaps, only fifteen or twenty, while, on the other hand, some of the social insects—bees, ants, termites—lay many thousands. Taking the termites, or white ants, as an example, Smeathman says that, owing to the number of eggs which she produces, the abdomen of the queen termite increases "to such an enormous size that an old queen will have it increase to fifteen hundred or two thousand times the bulk of the rest of her body." When this preposterous egg-bag commences to lay, she deposits eggs at the rate of about sixty per minute, so that she lays probably about 43,200 eggs in a day, and she continues at the work for many days. Insects usually deposit their eggs with rapidity and then die, many familiar moths expiring after laying only about one hundred eggs, although some produce considerably more. For example, the common large yellow underwing moths, which trouble the collector so much by their abundance when he is "sugaring" the trees for choicer game, lay their small yellowish eggs on almost every sort of plant, from grasses upwards, in batches of from six to eight hundred.

In addition to this amazing fecundity, several

successive generations of some species of insects may make their appearance in the course of a single year; and some, like the aphides or "green-flies," increase their kind by the production of living young, although they commence primarily at the beginning of the season from fertilised eggs laid at the end of the previous autumn between the winter scales of the leaf-buds. When the warm sunshine of spring persuades the buds to open, the young aphides or green-flies are there to feed and multiply upon the young leaves. No more eggs are laid until the autumn, for the offsprings of these eggs are not male and female insects, but all imperfect mothers which keep feeding and budding out young just like themselves, which again go on budding, and so on, until one aphis becomes the progenitor of billions of descendants in the course of its life.

Thus it might well have appeared to our forefathers, who had no accurate knowledge of the wonderful powers of increase of these tiny creatures, that the atmosphere was "freighted with insects' eggs that elude our senses," and that the honey-dew which these aphides exude came as "a peculiar haze or mist loaded with poisonous miasm."

Seeing in what abundance the green-flies are produced, it naturally follows that, unless some

check was placed upon their increase, all vegetation would soon be destroyed. Luckily, however, there are numerous enemies that prey upon them. Fig. 86 shows the pearly iridescent egg of one of the hover-flies—wasp-like flies that are often seen

Fig. 86. An egg of a hover-fly. × 25 diameters

poised by the rapid vibrations of their wings over plants—these flies usually place their eggs singly on stems and leaves amongst the aphides, and when the voracious young larva of the hover-fly emerges, woe unto those green-flies! The larvæ of these flies are remarkable for several curious features, considering the nature of their food. In the first place, they are blind; secondly, they are footless; and thirdly, they drop from leaf to

leaf when searching for aphides in an apparently reckless manner. Then it is most interesting and curious to see one of these strange grubs suddenly, on meeting with an aphis, pick it up clear from the branch, and then stand upright on its tail end away from the branch, and remain in this attitude while it devours it. Thus one juicy fly after another is taken, sucked dry, and its skin cast aside so rapidly that, in the course of an hour or so, a branch that was loaded with aphides becomes practically clean. And this is only one of the enemies of the green-fly. The pretty lacewing-fly also places its dozen or so of curious stalked eggs—so familiar on lilac and other trees—along the leaves and branches, from which the larvæ hatch and drop down to assist in devouring the aphides, protecting themselves by covering their bodies with their victims' skins, which they impale on hooks or spines on their backs. Thus to all appearance each becomes a portion of the stem itself covered with aphides as it moves about "seeking whom it may devour," and so it disguises itself from its own enemies.

In a later chapter I shall consider some parasites that trouble or benefit animal life; and it may prove interesting here to glance at a few of the eggs of these degraded animals.

Bird parasites present some remarkable forms in

their egg-structures; and although a number of these are not included in the class *Insecta*, but more

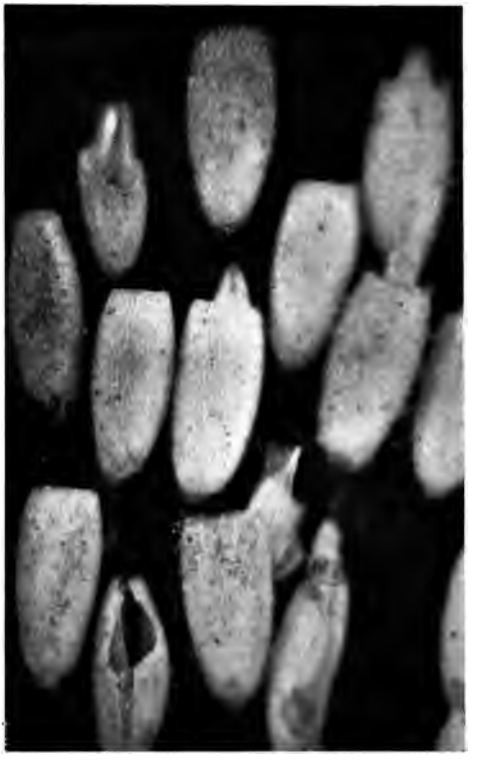

Fig. 87. Eggs of a bird parasite from the ground hornbill. × 20 diameters

nearly related to the spider family, yet I have included them here. Fig. 87 shows the eggs of a parasite of the Ground Hornbill; these are deposited

one above the other in almost parallel lines between the flattened barbs on the underside of the feathers.

Fig. 88 shows a peculiar blossom-like form

Fig. 88. Flower-like eggs of the parasite of the Australian mallee-bird. × 30 diameters

from the parasite of the Australian mallee-bird. Another of these flower-like examples appears in Fig. 89, this being taken from the turkey of Japan.

What purpose these lavish and varied decorations serve in the economy of the embryo is difficult to ascertain; but from experiments made it has been shown that the curved petaloid spines, when the egg is placed under water, rapidly un-

curl, and after straightening, contract on the lid, and remain contracted until all moisture has again evaporated, when they gradually assume their

Fig. 89. Other blossom-like forms from the parasite of the turkey of Japan. × 20 diameters

previous graceful forms. Possibly they offer some kind of protection, perhaps associated with a suitable atmospheric condition which may ensure the safety of the immature parasite.

One of the parasites of the fowl lays some curious eggs, which are illustrated in Fig. 90; while Fig. 91 depicts a number of eggs from

the parasite of the Pheasant, attached by its natural cement to the quill of the feather. And as a still further example from familiar birds, the prettily sculptured and porcelain-like eggs

Fig. 90. Eggs of a fowl parasite. × 25 diameters

of the parasite of the Peacock are shown in Fig. 92.

The living matter contained in the tiny eggs of insects is protected by three external coats. Beside the shell proper there is a delicate inner covering, and on the outside there is usually added a layer of material secreted from special glands at the time of depositing. This latter sometimes forms a coat for one egg, or a common capsule for a number, for all insects do not deposit

eggs singly, but some, like the common Cockroach or house "Black-beetle," produce a symmetrically-marked horny capsule which contains the eggs. This can frequently be seen by those who are unfortunate enough to dwell in cockroach-haunted

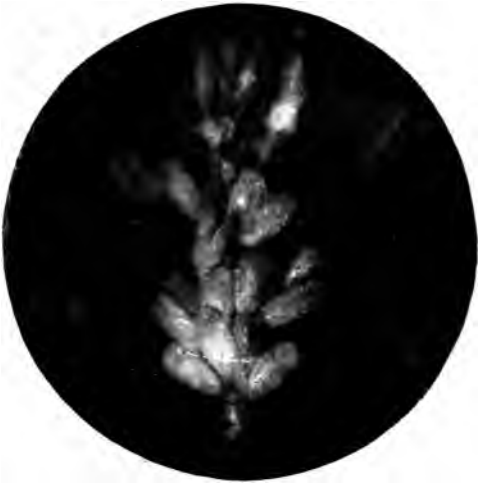

Fig. 91. The quill of a pheasant's feather with parasites' eggs attached

places, as the insect carries it about, searching for a suitable situation in which to place it for the young cockroaches to emerge.

A chapter on the subject of insects' eggs would be very incomplete without including some examples from the *Lepidoptera*, or butterflies and

moths. These are the insects which we admire most and recognise with the greatest ease; but, common as many of them are, comparatively few of us have ever observed the wonderful eggs

Fig. 92. Eggs of a peacock parasite. × 40 diameters

which they deposit upon almost every plant that grows in our gardens and fields.

If we carefully examine the leaves and stems of any plants during the summer months, and of some during the winter, we are almost sure to find some eggs of butterflies or moths; and we have only to place these under a good magnifying lens, or low-power microscope, to get revelations of some of the most interesting of Nature's minute marvels. If we like to take the matter seriously, a prodigious field of study is opened to us.

The eggs of most butterflies and moths are found upon or in the near neighbourhood of the food-plant of the young larvæ. And here is presented the marvellous instinct of the mother

Fig. 93. Eggs of a moth often found on cabbage leaves

insect: for she knows exactly what leaf-food her children will need, although she does not eat leaves and very seldom even obtains any part of her food from the same plant. Butterflies and moths in their perfect form have no mouth-organs —using the word in its scientific and not its toy-

shop sense—for masticating vegetable food, but instead a long, coiled, sucking tongue or proboscis, which they unroll to gather honey from the flowers. And if you watch any common White Cabbage or

Fig. 94. Eggs of Privet Hawk Moth as deposited by the insect. Natural size

Tortoiseshell butterfly that visits the garden, you will see how delicately the honey is sipped from the various flowers. And then the cabbage butterfly flickers away to some choice young cauliflower or cabbage and disappears beneath the leaf to deposit its eggs! In the same way the tortoise-

shell—if you are fortunate enough to have no nettles in your flower-border—leaves you for a period while she seeks among the rough herbage

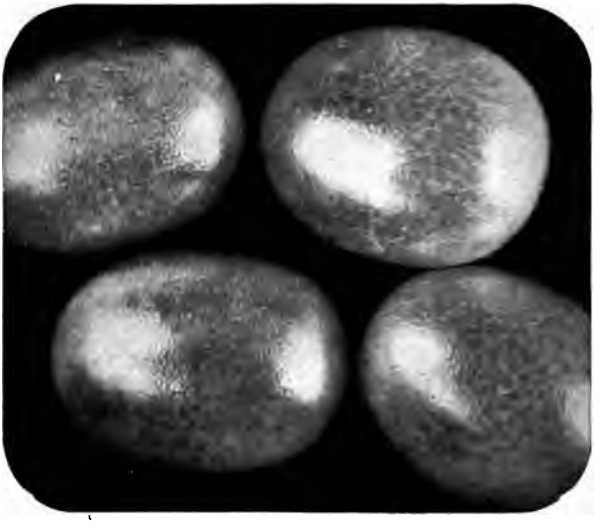

Fig. 95. Eggs of Privet Hawk-moth.
× 25 diameters

of some waste land for the stinging plant which her young caterpillars must feed upon. The instinct which guides these insects to these particular plants is one of the most interesting in the whole realm of Nature.

On the other hand, sometimes insects make unpardonable blunders in depositing their eggs in

places which give no hope for the future larvæ. Many moths, including lappets and swallow-

Fig. 96. The silvery reticulated eggs of the Currant or Magpie Moth. × 20 diameters

tails, in the giddy fascination of the electric arc and other street lights, become so enthusiastic as to leave their eggs carefully placed over the wires and globes ; while the other day my laundrywoman, in a mystified manner, brought me a few inches of an apron-string just taken from the clothes-line, which was "not like that when she hung it out."

A silly moth that usually deposits its eggs on

the cabbage had selected this apron-string as a suitable site on which to deposit, in a few separate batches, several hundred eggs. Fig. 93 shows some eggs of this Cabbage Moth, which is

Fig. 97. Eggs of the Blue Underwing Moth.
× 20 diameters

often most erratic in placing its eggs. Another batch from the same species on another occasion was methodically arranged on the outside of my window-pane. In this instance, as in the case of the moths which lay their eggs on street lights, the insect was probably blinded by the light from the inside at night time and, being unable to fly away, was obliged to lay her eggs where she could.

The pretty pale green eggs of the familiar and handsome Privet Hawk Moth are shown in Fig. 94

of natural size as placed by the parent moth, while in Fig. 95 several are given magnified

Fig. 98. Flat scale-like eggs of the Gray Chi Moth

to show their granulated and reticulated shell markings.

Fig. 96 exhibits the silvery reticulated eggs of the Currant Moth, which are placed upon the

leaves of gooseberry and currant bushes. Here the young caterpillar feeds for a time; but, as autumn approaches, it makes a silken hammock with a leaf for a covering, so that when the leaf

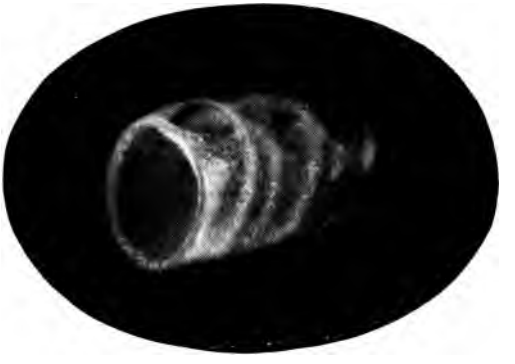

Fig. 99. Eggs of the Small Emerald Moth.
× 20 diameters

falls to the ground, it remains warmly wrapped inside. Here it abides in some safety for the winter; and in the spring it leaves its refuge to complete its feeding as a caterpillar before becoming a chrysalis. Fig. 97 shows another form of moth's egg, those of the rare Clifden Nonpareil or Blue Underwing. The eggs of the Gray Chi Moth (Fig. 98) present yet another type. These are flat and scale-like, with a slight tendency to project in the middle. The dark portion that appears at the centre of each is the young cater-

pillar coiled up within the egg, showing through the transparent shell. These were photographed just before the larvæ emerged.

Other moths lay oval flat eggs, like the Small

Fig. 100. An egg of the Brown Hair-streak Butterfly.
× 25 diameters

Emerald, Fig. 99 ; others, as many of the Thorn Moths, square, or oblong ones, which they glue in a line like a row of bricks along the branches. In fact, the varieties of form and sculpture in the eggs are almost as numerous as the moths themselves.

Butterflies' eggs offer equally attractive and interesting examples. That of the Brown Hair-streak is shown in Fig. 100. These white porce-

lain-like eggs may be found sometimes during winter in localities which this insect frequents, firmly glued to the twigs of the blackthorn, where they remain from autumn until spring. Fig. 101

Fig. 101. The eggs of the Small Tortoiseshell Butterfly. × 20 diameters

shows the eggs of the Small Tortoiseshell, which I have previously mentioned as being found on nettles. These are attached to the leaves in curious clusters or bunches of a hundred or thereabouts.

The sombre Meadow Brown Butterfly is familiar to every one about haymaking time as it flitters

about the lanes and open fields. It usually deposits its tiny and delicately marked eggs, illustrated in Fig. 102, amongst various grasses. As a concluding illustration (Fig. 103) I have shown the

Fig. 102. Eggs of the common Meadow Brown Butterfly. × 30 diameters

beautiful eggs of the Small Copper Butterfly, which a good search with a hand-glass, amongst dock leaves in wood-ridings and other places that this common insect frequents, may reveal.

What purpose do these artistic and microscopic sculpturings and engravings serve on eggs of insects? In all of Nature's minute works we discover the same lavish fecundity of symmetrical

details. Oftentimes the smaller the organism the greater is its beauty. Many of Nature's lowest creations, smaller by some thousands of times than these insects' eggs we have glanced at, reveal, under high magnifying powers, wonders that eclipse in beauty and elegance of workmanship

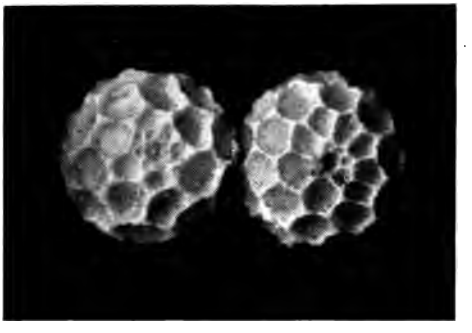

Fig. 103. The Small Copper Butterfly deposits eggs of this description. × 30 diameters

anything man can produce. We have caught a glimpse of these in the lower forms of plant life. The tiny seeds of garden flowers and weeds almost invariably reveal on their outer surface, when magnified, wonderfully diversified sculpturing and engraving; and it is not, perhaps, impossible that these often similarly coloured and engraved eggs of various insects gain a measure of protection from such enemies as ichneumons—

parasitic flies that deposit their eggs within the eggs and larvæ of other insects—when they are placed amongst the leaves and stems where seeds are continually falling as they ripen, by a natural mimicry or superficial resemblance.

CHAPTER VII

ANIMAL PARASITES

I MIGHT apologise to my readers for introducing such a subject; but science has no blushes. The term "parasite," as I intend it here, includes only those minute animals that infest other animals, either internally or externally. Most of them are nourished at the expense of their hosts, but some, such as the parasites of the pike and the pigeon, appear to confer a benefit upon them. In commencing we have to recognise one prominent fact. All living animals, great or small, are pestered more or less by other animals specially adapted to prey upon them. Man himself has more than fifty distinct species of known parasites. The dog and the ox furnish about two dozen species each; while the frog proceeds upon his watery way, accompanied by at least twenty kinds of these uninvited visitors. Even the slug, whose viscid secretions might be regarded as an effective barrier to all such trespassers, has its own special parasite, which plunges through the exudations of its host

with perfect freedom, and positively seems to revel in them. Some parasites are not by any means confined to one animal alone. There are catholic kinds which are found in or upon man, dog, pig, cat, rat, ox, &c., and always thriving. Canaries and other cage-birds produce a parasite or mite which often makes excursions to the persons having charge of them. The sheep-tick also occasionally attacks the shepherd. Others of this tribe, in addition to attacking mammals, are also found on birds, tortoises (Fig. 104), snakes, and lizards. Even the bullet-proof hides of the rhinoceros, and the leathery skin of the hippopotamus, are subject to the torturing inflictions of a tick. Horny skins or integuments are of no avail against the depredations of parasites, whom Nature has armed with complete sets of surgical instruments for the express purpose of penetrating them. The great whale of the deep is worried by them, in addition to the suckers, barnacles, and other external troubles with which his skin is sometimes so covered that it can only be seen in patches. The hide-bound elephant also has a special parasite with powerful mouth organs expressly adapted to penetrate his armour.

Neither do parasites cease to exist when we reach the lower shelves of Nature's museum of life. Insects, for instance, are no more exempt than

Fig. 104. Parasite of the tortoise

larger animals, as the parasite of the humble-bee shown in Figs. 105 and 106 will prove. The humble-bee from which this was taken alighted one day on the window-frame of the workroom of

Fig. 105. Parasite from a humble-bee, one of seventy-four taken from one bee

the writer, who, being accustomed to the habits of these insects, took little time to realise that something was amiss. The bee was performing some extraordinary gymnastics ; it seemed to be endeavouring to place its hind feet in the centre of its back, which for the bee is the most difficult portion of its anatomy to reach comfortably. Those who

study bees will know that a bee does not perform antics of this kind without a cause. So we must find the cause.

On taking up the bee and examining it with a

Fig. 106. The foreparts of another of the bee parasites more highly magnified

magnifying-lens, near to where the wings unite with the body, could be seen a small patch of pale yellowish colour, which I at once recognised as the cause of irritation and of the bee's gymnastics. The bee was without a doubt unwillingly enter-

taining a large number of very unwelcome guests. Next I washed the victim free from its irritating visitors, after which I counted these torturing mites, the family of which gave a total of seventy-four in all. Some of these I prepared for microscopic observation, and two of them I have photographed for the benefit of the reader. It will be seen in Fig. 105 that the two beak-like mandibles have a fuzzy appearance. On examining these organs under high magnifying powers, it is found that each opens at its end after the manner of pincers, revealing several teeth which fit tightly together when once they have gripped their prey. Their fuzzy appearance is due to their still retaining a portion of their victim in their grip. In Fig. 106 these mandibles will be seen to better advantage, being considerably more magnified. These elaborate jaws can be withdrawn separately, or together, into the interior of the body, and, I have good cause to believe, play an important part, combined with their curious, clawed feet, in making a holdfast while the bee is making its flight and entering flowers.

But the bee is not the only insect that is troubled with these unwelcome attendants. I have often taken specimens of some of our most familiar butterflies and moths, which entertained an embarrassing company of such visitors. The Red

Admiral, Small Tortoiseshell, Grayling, Marbled White, and other butterflies, may frequently be found with tiny, bright, scarlet parasites on their bodies and wings, while many moths are equally unfortunate, if not more so.

The destructive Winter Moth, for instance, is subjected to the attacks of no fewer than sixty-three known species of hymenopterous parasites, many of which attack it in the caterpillar stage. Butterflies are also very liable to the parasitic assaults of the hymenoptera, which are not always content with attacking insects in their caterpillar or larval stage, but often stoop to the meanness of depositing their eggs in the eggs of their victims. The contents of the eggs thus tampered with provide sustenance for the larvæ of the parasites, to the disadvantage of the embryo caterpillars which they were intended to produce.

Beetles, too, like other insects, have to play host to certain parasitic creatures, sometimes in large numbers. The specimen seen of natural size in the next picture (Fig. 107), was suffering when I found it from some of these parasitic visitors. When I removed and counted them, they numbered forty-three in all! This is by no means a large number: some beetles I have met with have supported double this quantity. The actual size of these mites may be judged by the

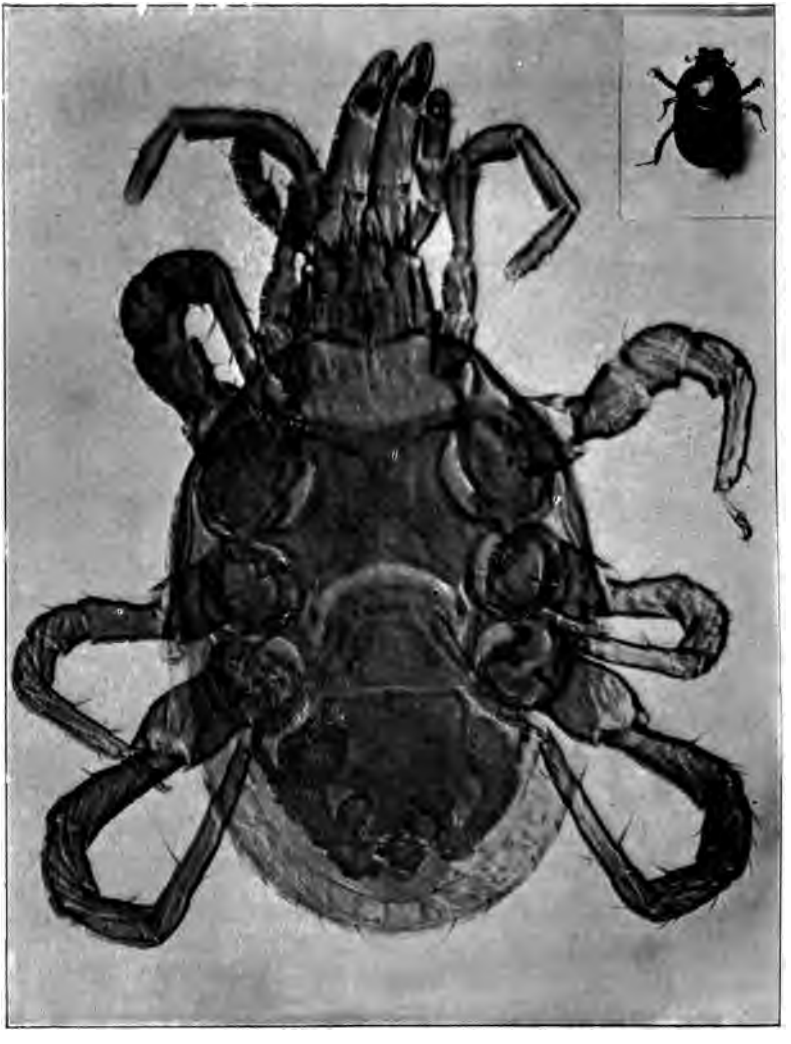

Fig. 107. The beetle in the corner was playing host to forty-three parasites like this

fact that at least four of them can find ample standing-room on the space occupied by the head of a pin. This parasite, like that of the humble-

Fig. 108. One of the pincer-like organs of the parasite of the beetle, holding a delicate fibre

bee, is possessed of a pair of pincer-like organs on its head, one of which is shown greatly magnified in Fig. 108.

As a concluding illustrated example of insect parasites we can perhaps find no commoner insect as a host than the common housefly, which every one may capture who desires to study its parasitic

visitors. Of course, these are rather small, and may present difficulties in observation. However, I have shown a few of these considerably magnified in Fig. 109.

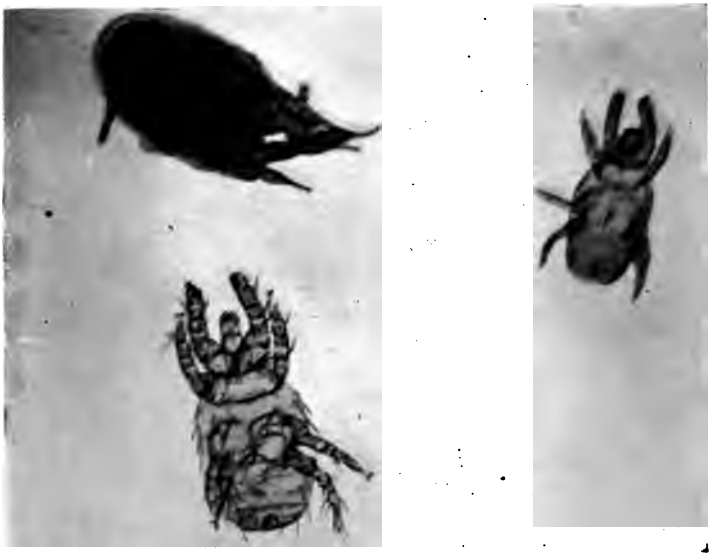

Fig. 109. Parasites of the common hous -fly

The small size of an animal gives no sort of immunity from parasitism. There are, for instance, many minute creatures that obtain their sustenance by living inside the tiny green-flies or aphides which so often infest our choicest plants. Thus parasites attack parasites, and the pheno-

menon called "hyper-parasitism" is brought about. Such secondary forms of parasitism are, indeed, quite familiar; and there is little doubt that tertiary parasitism occurs. Some, indeed, who are presumably competent to form an opinion, even contend that quaternary forms are well within the range of probability; as was clearly foreseen by the poet who penned the famous lines:

> Little fleas have smaller fleas
> Upon their backs to bite 'em,
> And these again have lesser fleas,
> And so *ad infinitum*.

The most interesting and, indeed, amazing aspect of parasitism is, however, presented by the case of those parasites which require several hosts to complete their life-cycle.

There is, for instance, a species of flat-bodied worms which produce that troublesome disease amongst sheep known as the "rot." These parasites are commonly known as "liver-flukes"; and supply a marked instance of parasitism within parasitism.

The eggs of the fluke first require to reach water, in which they develop into actively swimming embryos. At this stage they wait upon a particular fresh-water snail, whose body they enter, and there remain quiescent, but at the

same time undergoing certain changes essential to their perfect development. After completing this period, they leave the snail and take to the water again; and if it should happen that no sheep, in the act of drinking, offers them hospitality, they patiently encyst themselves on stems of grass, &c., growing out of the water, in the hope, apparently, that they will ultimately be eaten by a sheep. If this good fortune favours them, they finally complete their history in the bile ducts and liver tubes of the unfortunate animal.

One of the most recent and remarkable instances of parasites that require more than one host, which science has revealed, is that of the malarial parasite. It has been shown that this organism lives in one of the tiny blood-corpuscles of man; but here it only vegetatively increases its numbers. To breed and develop so that it can be conveyed to other human victims, it has first to be taken from the human blood by a particular species of mosquito—which insect I shall speak of and illustrate in the next chapter—then continuing its development in the blood-corpuscles of this insect. The perfect or malarial spores are eventually conveyed to man again when bitten by the mosquito.

On learning that a simple parasitic organism

should require two such widely removed animals as man and gnat or mosquito to complete its life-course, indeed, causes one to wonder what

Fig. 110. A sheep tick, magnified five diameters

other hidden marvels of natural life surround us unseen.

Of course this complicated change of hosts makes the probabilities of mature development with this class of organisms exceedingly small: which is a providential arrangement, for if the development of these pests were less complicated, animal-life might be in serious danger of extermination.

Besides the liver-fluke, the sheep has a number

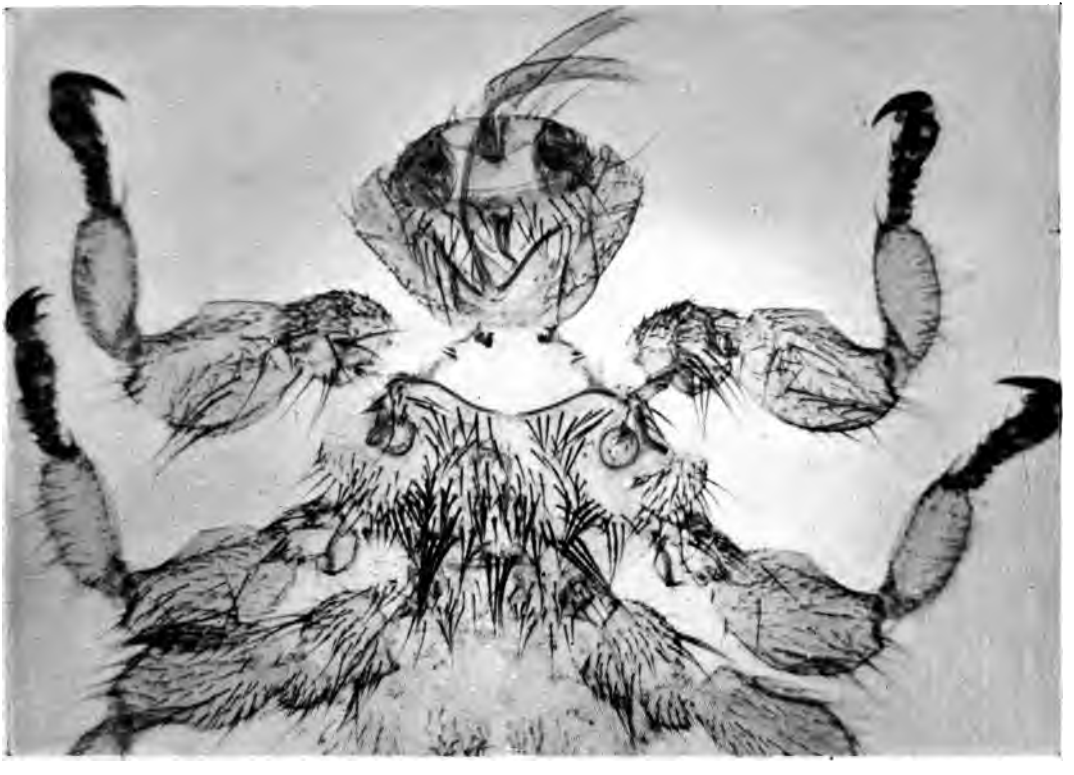

Fig. 111. The foreparts of a sheep-tick highly magnified

of adventitious troubles, conspicuous amongst which is the irritating "tick," which it tries so diligently to remove by rubbing itself against a gate-post or tree. The sheep-ticks, magnified representations of which are shown in Figs. 110 and 111, belong to a family of extremely troublesome creatures which in distribution may be said to be cosmopolitan; and in tropical countries they reach much greater dimensions than our British species exhibit. Ticks puncture the skin of the animals or birds on which they feed by means of a projecting beak, which is armed with recurved teeth and works in a kind of sheath, to prevent the escape of blood other than that which the creature is absorbing. The female tick thus pumps herself so full of her victim's blood that she assumes extraordinary dimensions.

A portion of the life of the sheep-tick, however, is not spent on the sheep, for they often occur on the ground, and probably to some extent are vegetable feeders. Pairing and hatching of eggs take place usually on the ground beneath stones, and in similar situations. But, when the craving for blood returns, they climb the stalks of grasses and other plants, and while holding on with their fore-limbs, extend their other legs and hooked claws, which are shown in the illustration, and await the passing of some woolly sheep, or if the

Fig. 112. Parasite of the pig

hungry creature happens to attach itself to the clothing of a human being, it will make the best of a bad job, and at the same time teach its host a lesson in natural history.

The pig, also, has its special persecutors of its own, and is often waited upon by the ferocious-looking creature shown in Fig. 112. Members of this family of pests also patronise the field-mouse, rat, dog, ox, ass, horse, rabbit, squirrel, camel, monkey, &c. They resemble each other very closely, although of different species; and one of the common characteristics of the various genera is the strong development of their legs, all of which, as our illustration shows, are adapted for climbing and holding firmly to their victim.

Birds, both great and small, suffer equally with mammals in the matter of troublesome visitors. The parasite of the ostrich shown in Fig. 113 is a formidable-looking example, but, taking into consideration the size of its host, perhaps it is only in the natural order of things. The parasite of the crow (Fig. 114) is content with more reasonable dimensions; and the common domestic fowl, along with many other familiar birds, provides board and lodgings for very similar parasites to this of the crow; while the pigeon, amongst its variety of such uninvited guests, possesses one at least of this family. Perhaps, however, the most interest-

Fig. 113. Parasite of the ostrich

ing of the pigeon's parasites is the one shown in Fig. 115, which is supposed to confer a benefit

Fig. 114. Parasite of the crow

upon the bird by thinning its body-plumage as the weather grows hot.

Similar slender-bodied and possibly useful parasites are found on many birds, including the domestic fowl, coot, water-hen, house-martin, &c.,

Fig. 115. Parasite of the pigeon

although of different species. The tawny owl presents by way of contrast (Fig. 116), a parasite that is not slender bodied, but exhibits an aldermanic outline suggestive of unearned increment.

Fish also have their personal attendants, and one of these, taken from the fresh-water pike, is shown in Fig. 117 ; this species is also found on carp, and perhaps more often on the small but interesting stickleback. It may seem to be upside down as represented in our illustration, on comparing it with the other pictures, but its position is correct. The legs are attached to the posterior part of its anatomy, and constitute paddles by means of which the creature can change its host, and depart to pay its attentions to another fish. The two dark spots seen in the forepart of the creature represent the first pair of legs, which have been converted into suckers, by means of which it retains hold of its slippery host. Perhaps, as is the case of the slender parasite of the pigeon, we do this fish-dweller an injustice by including him with those parasites that live more or less at the expense of their hosts. For there is good reason to believe that he is not a torment to his host, but rather a useful valet. In all probability it derives its nourishment from the superfluous products secreted by the skin of the fish. And when he has satisfactorily arranged

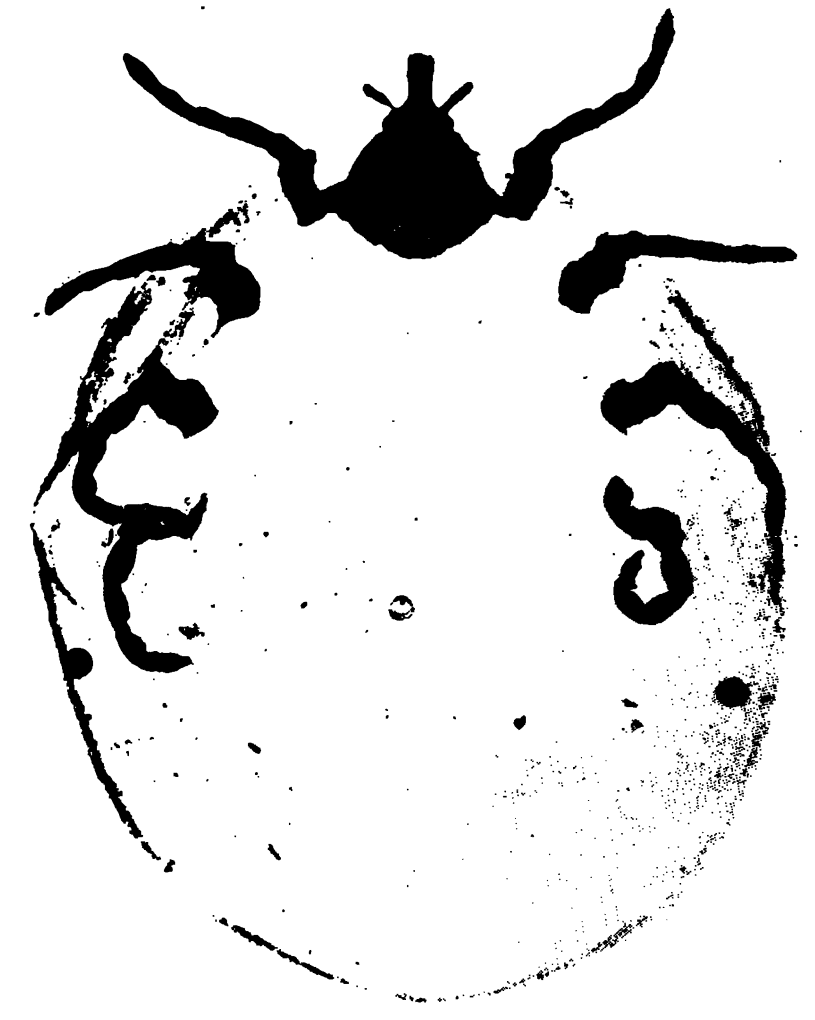

Fig. 116. Parasite of the tawny owl

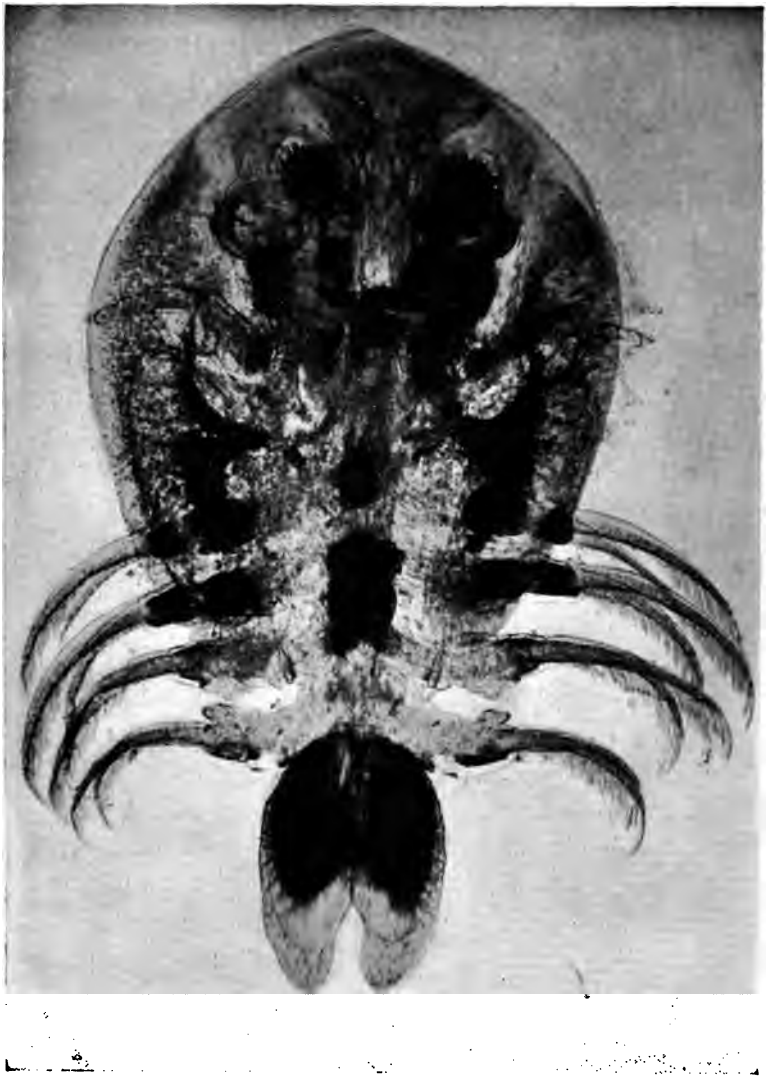

Fig. 117. Parasite common on pike and sticklebacks

the toilet of one host, he leaves his place for another with a more favourable field for his labours.

Fish have other organisms which take up their abodes temporarily on their skin surface ; for on my table while writing I have in a small tube of spirit a creature that I have just obtained from a roach. It is worm-like, about an inch in length, tapering slightly to one end. The broader end is terminated by a large sucker, and at the tapering end this is repeated on a smaller scale. This lively creature, with a sucker at its head and tail, was adhering by means of one of these suckers to the skin of the roach. It can detach itself at will, and, like our last subject, pass from one fish to another. Thus it is evident that fishes have to play host to various visitors at times.

While the study of these creatures which infest others may not at first present itself as a very agreeable subject, yet as we have seen, it possesses some exceedingly interesting features. As there are probably no animals that exist without their parasites, the study of these naturally provides a prodigious field for scientific work. There are many creatures of this class which are quite familiar to scientists, yet of whose life history little or nothing is known.

The difficulties in the way of the study of these

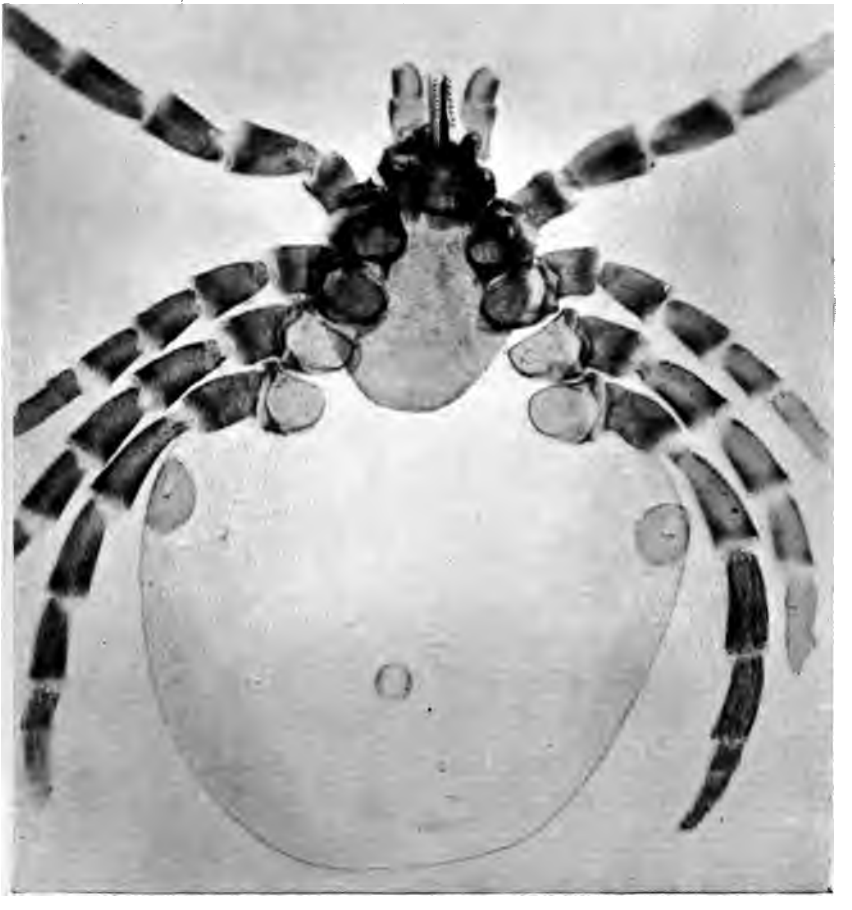

Fig. 118. Parasite of the polecat

Fig. 119. Parasite of the bat

organisms are of course very great. Animals like the polecat and bat, whose parasites I have shown in Figs. 118 and 119 respectively, are not perhaps animals which offer themselves readily for the purpose, but these are only the minor difficulties of the scientist.

CHAPTER VIII

INSECT WEAPONS AND TOOLS

INSECTS are provided with organs as wonderfully specialised as those of man himself to serve them in the fight for existence. Of course, I can only take a few examples to illustrate this fact; but every insect possesses some organ quite as marvellous as any that are shown in this chapter.

There are many insects which can inflict serious injury with the weapons they carry; though the injury is not always inflicted in anger or even in self-defence, but is usually the natural consequence of operations performed by the creature in pursuing its own vocation. Let us take, for example, the horse- or gad-fly, which preys upon horses, cattle, and domestic animals. Now, when an insect, perhaps barely an inch in length, attacks and pierces the tough skin of a creature like the horse, and sucks out a surprising quantity of blood, we naturally conclude that it carries some very special weapons. The micrograph given in Fig. 120 shows the remarkable

apparatus which is contained in the proboscis or trunk of the gad-fly. The organs with the sharp points, of which there are two, are the blades

Fig. 120. The lancets and blood-suckers of the gad-fly

which lance the hides of the unfortunate victims. The tip of one of these is illustrated, much more highly magnified in Fig. 121, showing what lance-like objects they really are. When

still more highly magnified they are found to be serrated like a saw on its cutting edge, the teeth being far too delicate to photograph for reproduction. The mandibles or lancets make the

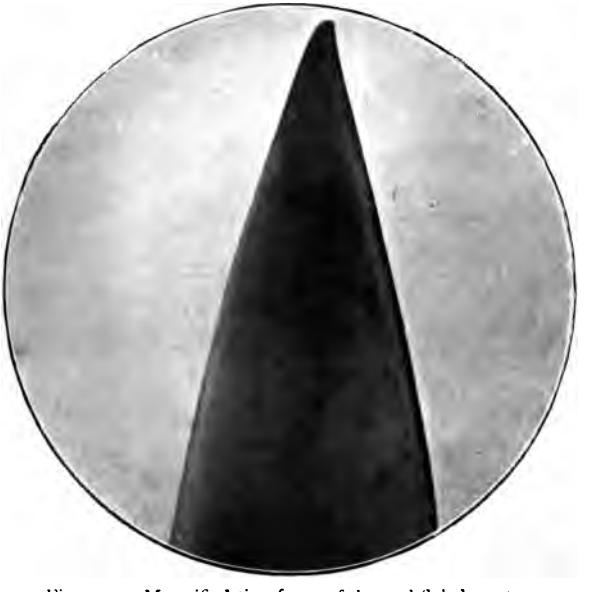

Fig. 121. Magnified tip of one of the gad-fly's lancets

puncture; the two *maxillæ* or blood-sucking organs on either side feel their way into the puncture and produce a larger flow of blood. As showing how perfectly adapted these organs are for this purpose I have reproduced in Fig. 122 the tip of one of these also on a larger scale.

Fig. 123 gives another view of the mouth organs of the gad-fly, and this will be seen to differ from Fig. 120 by the addition of the large dark organ occupying the central position. This, which in

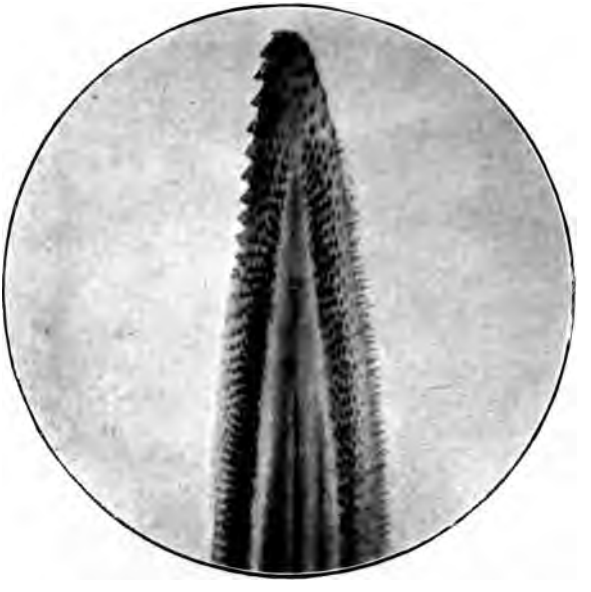

Fig. 122. Magnified point of gad-fly's blood-sucking organ

the former figure was removed for the sake of clearness, represents the *labium* or lower lip of the insect. There are two sucker-like pads or lobes at its end, which spread out upon the flesh of the victim, and so retain a firm hold

while the weapons are brought into play. The whole of these delicate yet strong weapons can be closed up within the outside sheaths, and thus

Fig. 123. Another view of the gad-fly's mouth, showing the large lower lip

form a tiny tube of surgical instruments that is barely visible to the human eye.

This voracious insect is by no means indifferent to man, though he prefers the brute creation. Not long ago, whilst fishing, a member of this family of flies alighted on the hand in which I

held the rod. Immediately I felt a sharp sting like the prick of a fine needle, but without pressure. I endured this; but as it was followed by a series of still more severe digs, I was compelled to remonstrate with vigour. When I looked at my hand I could see a tiny speck of blood. I thought no more of the incident at the time, but on the following day my hand was very irritable. The third day it was badly swollen; the fourth day I was compelled to call in medical assistance, as the inflammation was steadily increasing and my hand was seriously swollen. With suitable lotions things were put right again after a day or so. This is my own experience of a gad-fly's bite, which is evidently not without danger.

Recent experiments by eminent naturalists and medical men tend to show that the most formidable of insect pests, the *Anopheles* mosquito, conveys by its bite the disease known as malaria. I have, in Figs. 124 and 125, photographed the heads of both the male and the female of this particular mosquito. The latter alone possesses the blood-sucking organs in entirety. The male may be distinguished by his pretty hairy antennæ, and is harmless. The mouth-organs of the female are in every way similar to those of the gad-fly. The fine threadlike-looking lancets are found, when greatly magnified, to have barbed tips very similar

to the tip of the sting of a wasp, which will be shown in a later illustration. The weapon with

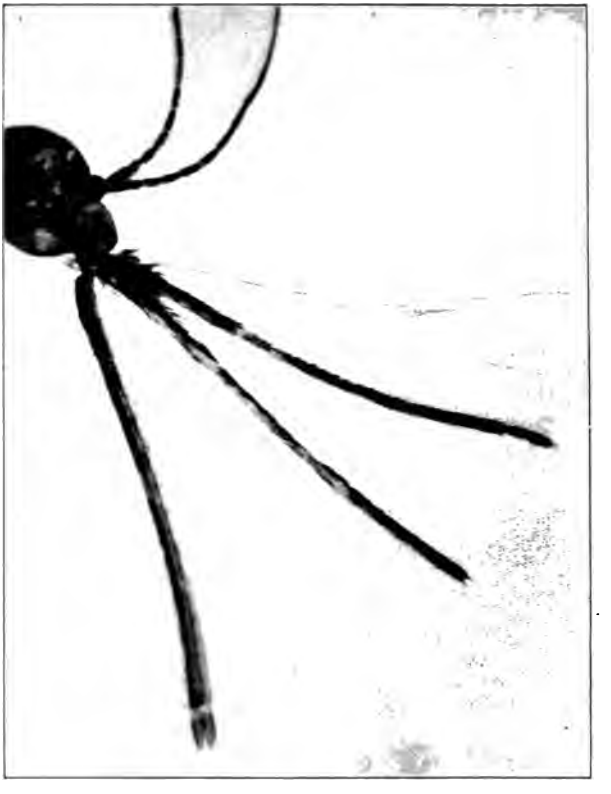

Fig. 124. Mouth-weapons of the female mosquito, showing lancet

the divided end is the one referred to in the case of the gad-fly as serving for a sucker to hold firm

to the flesh of a victim while imbibing its blood. Compare the delicacy and strength of these micro-

Fig. 125. Head of a male mosquito

scopic organs, and the neatness and perfect order in which they are put away when not in use, with any modern, highly finished case of surgical knives

or lancets, and we see at a glance that between Nature's work and man's there is no comparison.

Turning with relief from the winged insects which suck our blood to those which merely spoil

Fig. 126 The mouth of a wasp

our fruit, perhaps the reader would like to see the organs by which a wasp can bite or cut so deeply into a plum or a pear. These are shown in Fig. 126. The large, toothed mandibles at the side are the mischievous weapons, which work sideways, and not from above or below, as human teeth do. The delicate and beautiful tongue can be seen in the centre, with other organs

which serve various purposes in the insect's daily life-work.

And here I will leave the insect world for a moment, to illustrate the mouth-weapons of the common spider. When a hungry spider attacks a fly as big as or larger than itself, it exhibits a

Fig. 127. Mouth of a spider, showing poison fangs and teeth

confidence in its own powers which is usually justified by results. Look at the illustration of the spider's mouth in Fig. 127, and note the "business" ends of its chief weapons. These two terrible fangs, opening out from the mouth, are connected with a poison duct in the head of the creature. The method of the spider is first to poison his prey, and then to crush its victim with the apparatus below the fangs, which the illustration well shows; after which

process the creature has the juices of his victim at his disposal.

The spider has many weapons with which to hold its own, but on the other hand it has many weapons opposed to it. There are some kinds of wasps which feed their young upon nothing but spiders; and you have only to watch a spider that has a bee in its web to see that it understands what a sting means. It may be said, however, that the spider chiefly lives on flies, which have practically no weapons to defend themselves. Yet it is worth while to see a fly's foot under a good microscope (Fig. 128) (and a fly has six feet). The fringed pads are the means (assisted by the sharp claws) by which it performs that familiar but curious feat of defying the laws of gravity and walking upon the ceiling. The claws get a certain hold in the tiny crevices, too small for our eyes to see, while the pads are furnished with a large number of trumpet-shaped hairs, which secrete a viscid fluid of sufficient strength to bear the insect's weight. And so in autumn when flies begin to die, we frequently find them quite dead, yet holding firmly to our walls and windows. This happens when the viscid fluid has been duly secreted, but the fly has become so weakened that it has been unable to detach its feet again.

While considering these curious pads of the foot

of the fly we will look at another insect, one of our British diving beetles (to be found in ponds and small streams), which also has an apparatus

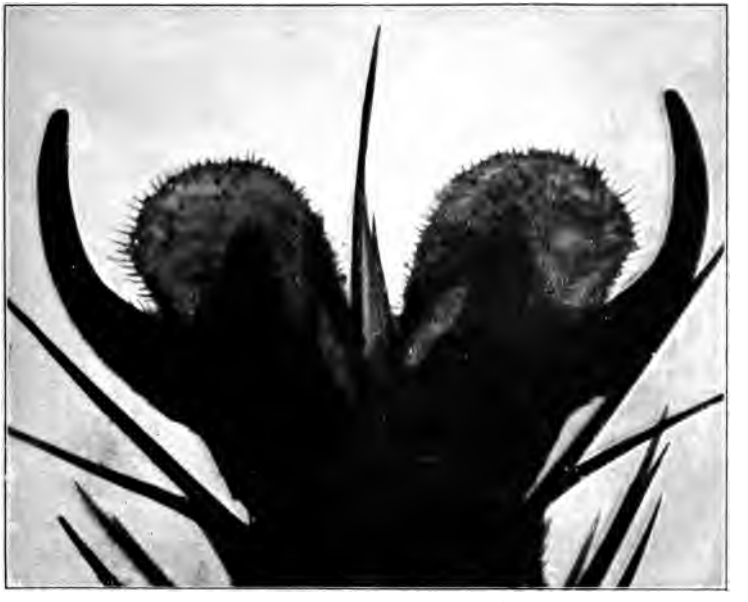

Fig. 128. The foot of a fly

for secreting a viscid fluid for the purpose of firmly holding on to whatever the insect desires to capture. These beetles, the veritable sharks of our pools and ditches, are extremely fierce, and attack young fish, frogs, and anything small which lives; but, inasmuch as the male alone possesses these

adhesive feet with the sucker-like prominences, it is probable that they are only used for capturing the object of his affections. One of his forefeet is shown, highly magnified, in Fig. 129.

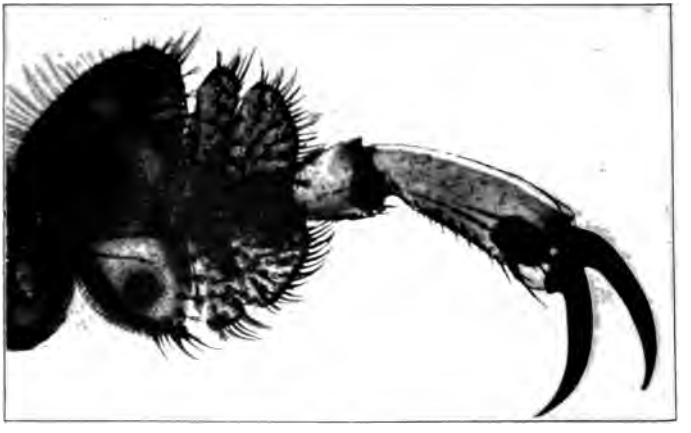

Fig. 129. Foreleg of a water-beetle

The next picture illustrates in Fig. 130 a more beautiful form of the leg of a water insect. This is the feathered oar of the water-boatman, which may usually be seen quietly floating on the surface of ponds, but, curiously enough, with its back downwards. This may seem awkward from our point of view; but the creature lies in wait, apparently motionless, with oars spread out, until a victim approaches, when the oars are flashed through the water, and the prey is caught from

beneath, and this peculiar habit of living upside down thus assists it in this method of assault. The shark of the ocean is much more clumsy, because he swims right side up and has to turn over to catch his prey, and while he is turning it often escapes.

A discourse upon insect weapons would not be

Fig. 130. Feathered oar of water-boatman

complete without considering at least one insect sting; so we will look at the illustration Fig. 131, in which I have dissected out the poison bag and sting of the common wasp. The poison bag is seen above, being a reservoir of formic acid, which the insect uses when angry. The two stings are removed from the sheath, that is the dark-coloured organ which may be seen beneath. If the sharp ends of the stings are carefully observed they will be seen to possess a row of minute teeth or barbs.

Thus it will be seen that insects, like human beings, carry cutting weapons and wear them for

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safety in a scabbard. But one would hardly expect to find an insect carrying a bayonet,

Fig. 131. Poison bag and sting of a wasp

like the ichneumon fly whose weapon is illustrated in Fig. 132, for the express purpose of plunging into living bodies in order to make a hole for its eggs.

The living bodies in this instance happen to be caterpillars, and, after the fly has drilled its

Fig. 132. Egg-depositor of the ichneumon fly, an insect which is armed with a bayonet

holes and laid its eggs, the larvæ issuing from the latter are nourished at the expense of the caterpillar, which has an enormous appetite, but gets thinner and weaker, while its boarders get plump and healthy. Finally, when the

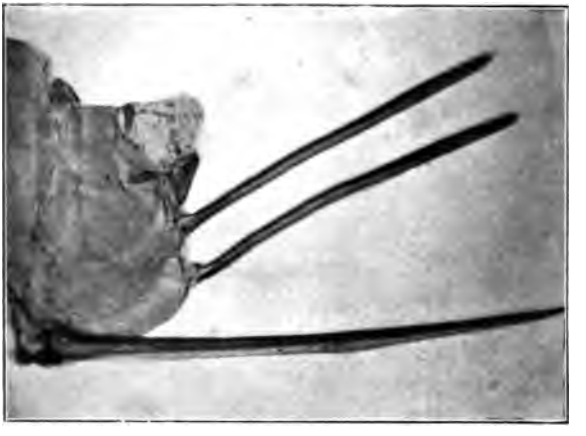

Fig. 133. Another insect bayonet

caterpillar has completely exhausted its resources, the young ichneumon grubs are ready to become chrysalids before their future winged state. If it should happen that the mother ichneumon fly has selected a caterpillar that is somewhat developed, so that it requires to go into the pupal or chrysalis stage before the young ichneumon grubs have finished feeding, this in no way incon-

veniences the parasitic visitors, who remain and eat the chrysalis. The latter, it is needless to

Fig. 134. Ichneumon fly's foot, with claws for holding on

remark, never becomes a butterfly. Another weapon from another species of ichneumon is shown in Fig. 133. The pair of long hairy organs seen in each illustration are sensitive organs or

feelers by which the insects are guided in depositing their eggs.

A foot from the same ichneumon is shown in Fig. 134. One might think that the poor cater-

Fig. 135. Ichneumon fly which lays its eggs in "blight"

pillar would have enough to endure from the ichneumon fly in the way of torture without the addition of six pairs of these comb-like claws gripping its soft body, to persuade it to gentle submission to the egg-depositing business.

All ichneumon flies do not select caterpillars as

their hosts; for some species lay their eggs in green aphides or blight so much too familiar on

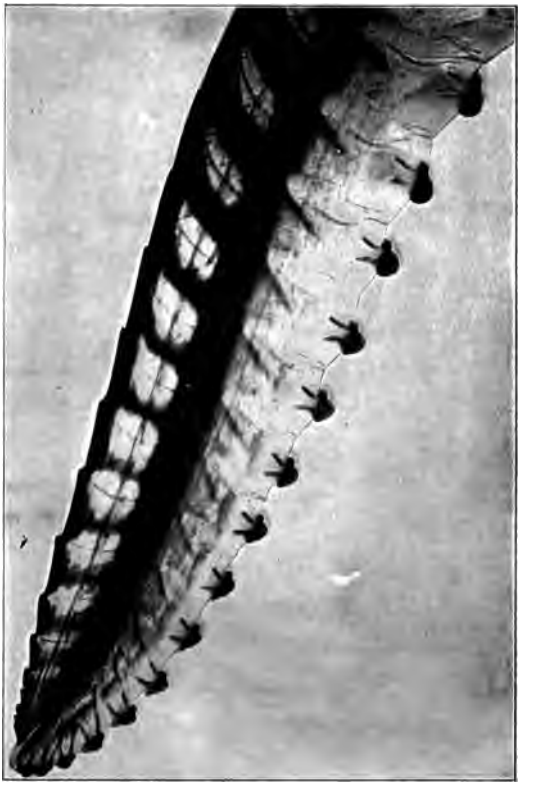

Fig. 136. The tip of one of the saws of a saw-fly

rose, and other plants. One of these tiny flies is shown in Fig. 135, considerably magnified. Other

species prefer even to deposit their eggs within the eggs of their victims.

Another form of insect weapon one would hardly expect to find is a saw for perforating the branches

Fig. 137. The saw-fly's weapon

of trees (Fig. 136). These tiny saws, the backs of which work in grooves alternately, are used by saw-flies for the same purpose as the weapon of the ichneumon fly—namely, for cutting incisions in which to deposit eggs. The only difference between them is that in this case a saw is used upon wood-tissue instead of a bayonet

upon flesh, the eggs being placed in a suitable place beneath the bark of young bushes and trees—where the eggs hatch and the young caterpillar-like grubs issue forth just when the young leaves are fresh and tender. Each female saw-fly carries a pair of these saws, which are shown in Fig. 137.

And so we would find that every insect has some special organ or organs to suit its own particular purposes; for these micrograph illustrations have been taken almost at random; and a systematic illustration of the equipment of the insect-world for warfare would multiply types far beyond the containing power of this modest volume. So I hope that one result of this chapter may be to create an interest in insect life in the minds of some who hitherto, perhaps, have regarded such small life as matter only for contempt and loathing.

Indeed, the weapons and tools of insects form a study of all-absorbing interest. The spider with its wonderful spinnerets weaves its snare to entrap its prey, while with its comb-like feet it manipulates the quick-spun thread to enshroud its victim before storing the carcase in its larder. The caterpillar has minute hooklets to its feet (see Fig. 138) to enable it to hold firmly to the branches and leaves while seeking for fresh green foodstuff; and, like the mountaineer who climbs great heights, he

often provides himself with a rope for safety, if he should lose his foothold. The caterpillar's rope is a silken thread, which prevents it falling to the depths below, whither a sudden jerk of the branch would otherwise precipitate it.

Fig. 138. The caterpillar's many-hooked foot

CHAPTER IX

MAY-FLIES AND THEIR NEIGHBOURS

AQUATIC insects especially offer to observers of Nature a fascinating field for study, because they are so markedly specialised to suit their surroundings.

Standing by a clear pool on a bright day of early summer, and gazing into the depths by the aid of the brilliant sunlight, you catch many glimpses of strange living forms. Curious grub-like creatures may be observed slowly crawling here and there amongst the mud and vegetation at the bottom. Others with more lively habits will, without apparent effort, dart through the water after some unsuspecting victim; or perhaps, creeping about the mud and weeds, some of the caddis-worms will be seen half protruded from the ingeniously-built dwelling-places which they drag behind them.

Nor need you always stare into the water to see its interesting insect life. Nothing is more curiously fascinating than the mazy dancings of a swarm of the May-flies which appear on

the wing in vast numbers towards sunset in spring.

These insects, as well as dragon-flies, alder-flies, and caddis-flies, are invariably associated with aquatic surroundings. But why? Because, while we gazed into the pond at those strange grub-like creatures, *we were only taking a preliminary peep at these flies in their early or larval stages*, just as, when we examine a caterpillar we read only the first—or, to be correct, the second—chapter in the history of a gorgeously coloured butterfly or moth.

Generally speaking these aquatic insects spend by far the greater part of their lives beneath the water, after which their existence in the winged or perfect state lasts for a very short while, usually just long enough for an abrupt mating and laying of eggs. This of course will bring again to mind the fairy May-fly, so frequently referred to as the type of brief and ineffectual life. But in these references to the brevity of the life of this insect it is the moraliser's misfortune that he has somehow forgotten the two or three years of life-history through which it at last reaches the winged state.

Indeed the life of the May-fly is by no means short, considered from an insect point of view, although it is true that in the winged state its

span is brief, maybe but an hour, or even less according to some authorities. Réaumur considered that individuals living from the evening of their emergence until the sunrise of the next day would be Methuselahs in a tribe of which the greater number never see the light of the sun at all. Although Nature provides these insects with wings but for "the sport of an hour," it does not follow by any means that she slights her work on that account. I have shown in Fig. 139 a portion of one of the wings of a May-fly considerably magnified, to exhibit its beautiful veinwork and structure. With the eyes of the May-fly, too, Nature has taken infinite pains in some species—for there are about forty species in Great Britain—enriching them with seven eyes of three kinds. Two of these are compound pillared eyes and are raised above the head; then there are the two ordinary compound eyes of insects, which are generally on either side of the head, while between these and in front of the head there are three ocelli or single eyes.

Another interesting point in the anatomy of the May-fly is its mouth. As it neither requires nor has time in its winged state to eat or drink, its mouth organs become atrophied, leaving nothing but a small air passage which leads to the alimentary canal. The latter, however,

Fig. 139. Portion of the wing of a May-fly.
Highly magnified to exhibit the structure

remains, and, remarkable to say, becomes of greater dimensions than is usual, the stomach forming a capacious sac.

The older naturalists observed what graceful balloon-like movements the "dancing May-flies" possessed, but it is only of recent date that this buoyancy has been satisfactorily explained. It has now been found that their movements cause air to enter at the mouth which distends the stomach sac, the orifices of which are then closed, the result being that each insect becomes a living balloon.

The earlier life of the May-fly is somewhat haphazard, for the eggs are committed to the water in lumps without care or foresight on the part of the parents. As a rule these egg-clusters separate rapidly and the eggs sink broadcast to the mud below, though some species of the flies creep down into the water and deposit their eggs carefully under stones and in other safe situations. The eggs often remain until perhaps February or March of the next year before hatching. When the larva emerges it has no respiratory system, but gills soon begin to appear, and growth seems to take place but slowly. After moulting its skin perhaps some twenty times—each moult making it differ in appearance—within the period of its one, two, or three years' growth, according to the

species, its metamorphoses are completed, and the animal leaves the water to become a winged May-fly. Fig. 140 shows the larva of a May-fly.

It is a mistake to suppose that May-flies only

Fig. 140. Larva of May-fly.
× 4 diameters

appear during May, as various species arrive at maturity at different periods during the summer months. But the regularity of emergence of each species is remarkable, and the phenomenon of the sudden appearance of immense swarms without any warning is a spectacle which familiarity never stales.

The *rise*, as it is called, of the flies usually takes

place towards sunset in still weather, and the almost simultaneous emergence of myriads from their pupæ is one of the most remarkable phenomena of insect life. The most attentive observers have failed to detect an interval of more than a few seconds between the floating of a pupa or nymph to the surface of the water, the cracking of its skin and the flight of the winged insect into the air.

But a most curious second emergence has still to be performed, for the insect is not yet freed of its vestures, being enveloped in a superfluous, glove-like skin which has to be got rid of. So it alights on some plant-leaf or stem to complete its development, and there gradually frees itself from all restraining bonds. Sometimes in so great a hurry is it to soar on the newly developed wings, that it will ascend before this last skin is removed, finishing the process of development in the air, and looking like two flies, for this skin is a perfect image of the insect, even reproducing the long and slender tail filaments. Fig. 141 shows a magnified representation of one of these cast skins.

If difficulties should arise in this last emergence, occasionally the flies will mate without completing their development, and quite a large number die without casting this last skin. If we

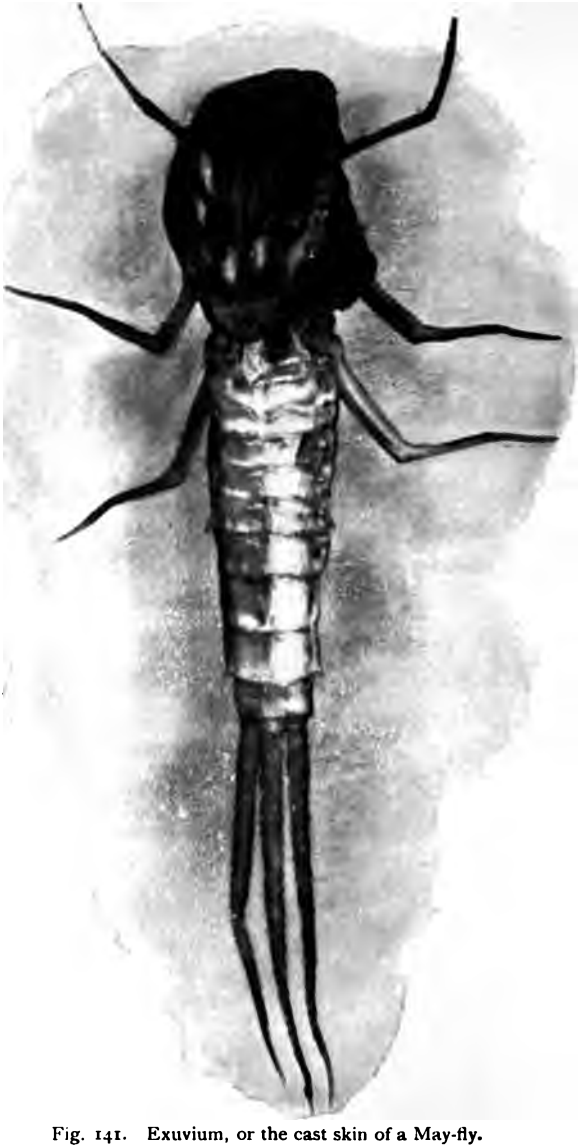

Fig. 141. Exuvium, or the cast skin of a May-fly.
× 20 diameters

examine the May-fly at this stage in its life-cycle, we observe that the insect is of a dingy hue or grey colour, without a spark of the brilliant iridescence of the wings and body of the perfect May-fly as it flashes in the evening sunlight. Secondly, its forelegs seem too short; and its tail filaments seem blunt and brief, even its wings are cramped and small. But we must wait awhile. Our insect is resting from the great effort of its recent emergence. After a time, which varies very much in individual insects, a little trembling sensation seems to take possession of the May-fly, and then a most beautiful and marvellous emergence and transformation may be witnessed.

The skin at the back of the head splits, and slowly the head and forelegs of the perfect insect appear through the broken integument, and, most remarkable to see, the forelegs have nearly doubled their previous length. After the head and forelegs are through the insect draws itself forward until its wings and the remainder of its body gradually leave their glove-like vesture, and the same remarkable feature strikes the observer in the apparent telescopic expansion of every part as soon as it leaves this "*subimago*" skin. The wings become glossy and sparkling as they leave the delicate integument, and the latter almost immediately collapses as the wings are withdrawn.

But most wonderful of all is the withdrawing of the tail filaments, seeming almost like the work

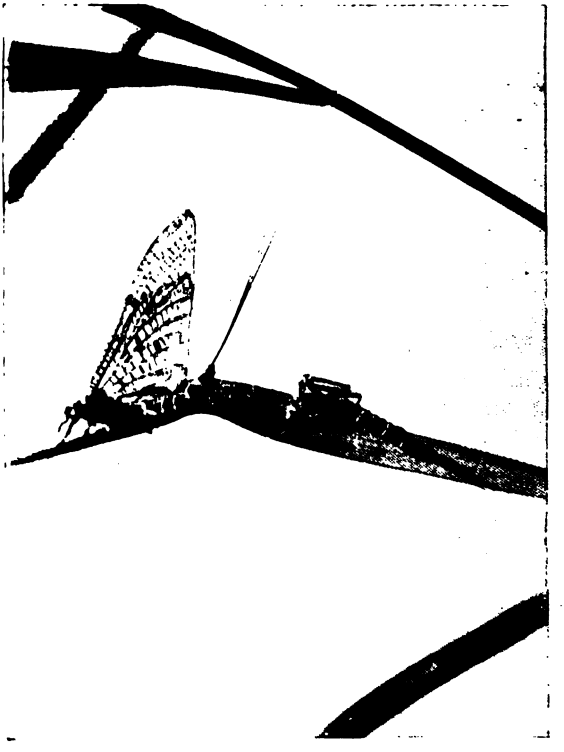

Fig. 142. The perfect May-fly just emerged from its *subimago* skin, which latter can be seen on the grass blade. Natural size

of a magician, as these appendages, nearly three times the length of their cases, are withdrawn. If you saw a man draw a six-foot sword out of

a two-foot scabbard, you would say that there was some conjuring trick or sleight-of-hand; but the May-fly does what is practically the same thing, as a natural detail of its development.

Fig. 142 shows the brilliant and fully-developed May-fly just emerged and prior to its flight, leaving its *subimago* skin on the grass blade behind. It is almost saddening to think how often these miracles are performed in vain, for incalculable myriads of these flies perish so soon as emergence takes place, being devoured by fishes, swallows and other birds.

During the five or six hours which is probably the average time of their winged life, the female May-fly finds a partner, and the eggs are scattered upon the waters. And at the end of this time the prodigious swarms of insects, in which the males largely predominate, fall away as the individuals gradually become weaker and weaker, and the fish enjoy a feast which is probably equivalent to our "strawberry season." Some species develop large swarms for several successive evenings, and then that generation of the species disappears beneath the water for some two or three years, although, of course, alternate generations make an unbroken annual emergence; while other species, notably the Common May-fly, may emerge in moderate numbers during the

evenings for a fortnight or three weeks. Fig. 143 shows a May-fly, natural size.

In the intervals of watching the easy and graceful flight of the May-flies we may have observed, rest-

Fig. 143. A May-fly. Natural size

ing on palings or stones near at hand, a number of black-bodied flies, with thick and conspicuous dark-coloured veinings on their smoky wings. These common insects are known to anglers as alder-flies. Fig. 144 has been prepared to show their anatomy. This is another of the insects which are always associated with water ; the female deposits an enormous number of eggs in patches on rushes or other aquatic plants. A number of these are shown in Fig. 145, being dingy brown in colour and

oblong in shape, with a narrowed point at the top, and arranged standing on their ends. Generally there are many hundred eggs in each cluster. Sometimes the eggs are placed several yards

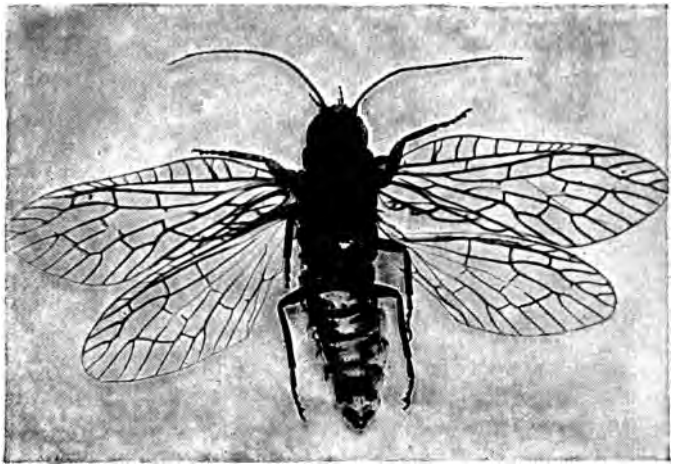

Fig. 144. An alder-fly. × 3 diameters

away from the pond, which makes it extremely awkward for the young larvæ when hatched, for their aquatic instincts at once manifest themselves. However, they proceed with all possible speed to the nearest water-course and so drift down to the ponds, and at once become denizens of the muddy depths. How they find their way is one of those instinctive mysteries often exhibited by insect larvæ. These larvæ feed on other insect-larvæ,

notably those of the May-fly and caddis-fly, for which purpose Nature has provided them with a pair of powerful biting mandibles, which may be seen in the illustration Fig. 146. The filaments

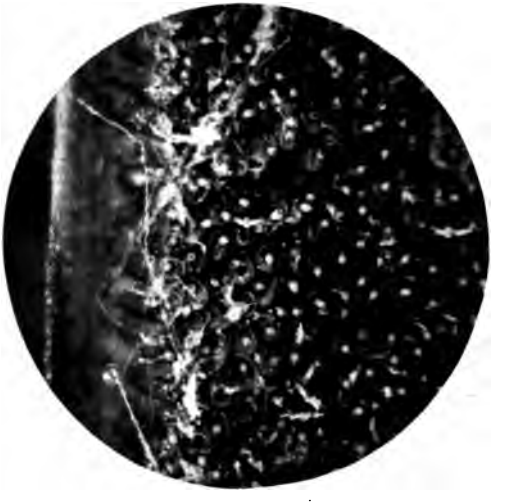

Fig. 145. Eggs of the alder-fly on the leaf of the common iris or yellow flag

which appear at the sides of the abdomen are the animal's breathing organs.

About May or June the larva has done feeding; it leaves the water and burrows in the earth, perhaps several yards from the pond ; and thence, after an interval of two or three weeks, the clumsy fly emerges. They are quite easy to capture, being slow on the wing.

Of the caddis-flies the British Isles have no fewer than 150 species. The larger of these insects begin to fly as night approaches, being of nocturnal

Fig. 146. Larva of the alder-fly.
× 3 diameters

habits. Hence they may readily be mistaken for moths. Their wings are semi-transparent and of various shades of brown, occasionally adorned with markings, though they have not the innumerable tiny scales arranged on each side as in the case

of moths. Fig. 147 illustrates a caddis-fly, which has been slightly magnified in order to show its structure.

Caddis-worms divested of their cases are familiar

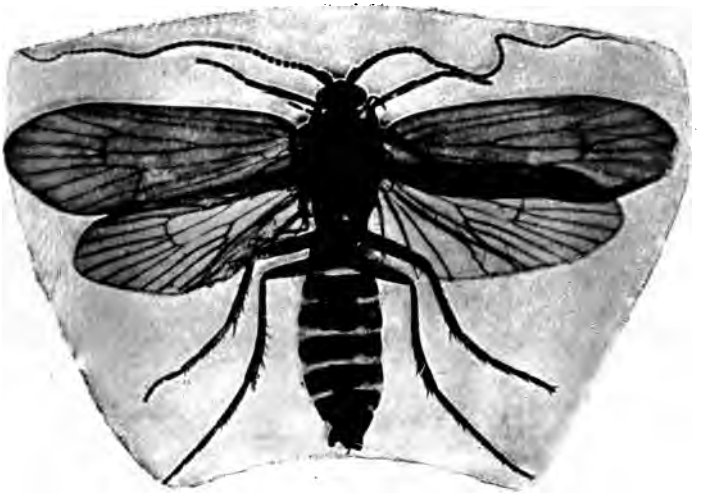

Fig. 147. A caddis-fly. × 3 diameters

to every disciple of the "gentle art." In Fig. 148 one of these is shown slightly magnified. The head and legs are protected by being hard and horny, but the hinder part of the body is white and soft, and it is to protect these parts that the larva so assiduously builds its portable tunnel.

The larvæ of these insects are extremely interesting on account of this curious habit of

building cases or tubes in which to protect the more tender parts of their bodies from sticklebacks and other enemies. As soon as they leave the

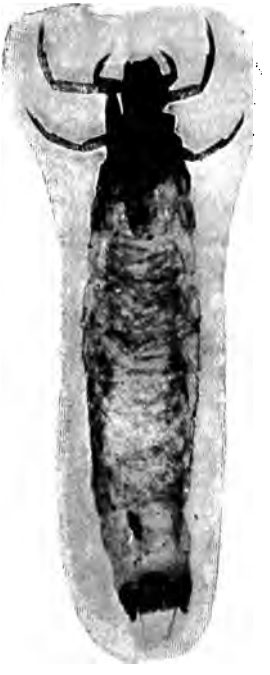

Fig. 148. A caddis-worm denuded of its case.
× 4 diameters

egg the caddis-grubs commence building, the different species and families each manufacturing their dwelling-places in different forms and of different materials. Even individuals of the same

species will often use a variety of substances which happen to be near at hand. Fig. 149

Fig. 149. Specimens of the cases built by caddis-worms. Natural size

shows a number of these cases made of various substances and in many forms. The first is built of water-logged bits of stick cut to suitable sizes

by the larva; the second is composed of comparatively large pieces of sandstone; the next in order is a neat form made of minute pieces of wood cut into nearly equal lengths; four and five are the homes of species which often build their cases of rushes combined with various shells of water molluscs. These latter are used with or without the consent of their tenants, who, when once attached by the insoluble cement of the caddis-worm, become close prisoners and are dragged hither and thither entirely at the mercy of the grub. Number six represents another case built of stone, with one large stone attached at the side to make up for a general deficiency in weight. This kind of weighting is frequently done when the case happens to have been made too light in the first instance. Number seven is formed of convenient lengths of rushes; eight is composed of everything as yet mentioned, including shells, stones, wood, rushes, &c. In nine and ten, however, we get a new variety, for these are thin tubes built of tiny grains of sand closely cemented together, to the outside of which are long twigs fixed, like the heavy stone of the former instance, for the purpose of giving a balance. The bottom row shows some of these forms as they appear end on.

These aquatic architects arrange and build

their tubes in a remarkably short time. From several of the cases shown on the photograph I had to remove their inmates for the purpose of

Fig. 150. Magnified view of the end of the body of a caddis-larva. Showing the hooks by means of which it retains attachment to its case

this illustration. These I then supplied with the remnants of one or two old cases, which, after turning them over suspiciously for some time, while probably thinking of hungry sticklebacks, they at last proceeded to work together with all speed into new cases. From the time of removal

of their own cases until they were completely encased in a new tube, they occupied just about three hours : which, considering that they had no choice

Fig. 151. A large dragon-fly.

of material other than that provided, appeared to me to be rather smart work.

To remove a caddis-worm from its case is no easy matter, and if I refer my reader to Fig. 150, where is shown a magnified view of the latter end of the body of a caddis-grub, showing the horny hooks by means of which it retains hold of its

sheath, I think that the statement will readily explain itself.

In concluding we may just glance at the dragon-flies, whose larvæ of many various kinds

Fig. 152. Larva of a dragon-fly.
× 3 diameters

are to be found in all ponds. These insects, of which one of the larger species is shown in Fig. 151, have a fearful reputation as horse-stingers, and are not infrequently called hornets and severely left alone on that account. As a matter of fact they are quite incapable of stinging, as they possess neither stings nor

poison-bag, and may therefore be handled with perfect safety, in spite of the formidable and menacing flourish of their tails.

Fig. 152 shows the larva of one of the smaller and more delicate species of dragon-fly frequently observed flying over and around ponds. In front of the head will be seen a kind of projecting organ called the "mask," which, however, is really its lower jaw. This the larva is able to withdraw and hide beneath its head, in which position the mask lies in wait until some unwary victim is in close proximity, when it suddenly projects forward, and the prey is secured and dragged back to its death. The mask then holds the prey to the true mouth and jaws of the voracious young dragon-fly, much in the fashion of an elephant's trunk. To show what a really formidable weapon this lower jaw or mask is, I have shown it considerably magnified at Fig. 153.

When these insects reach the winged state they become familiar objects, with their handsome metallic colouring and striking speed of flight—a wonderful contrast from their early, crawling habits at the muddy bottom of the pond. Their gauzy wings flash in the sunlight as they dart past at a pace that is simply astonishing, considering that it is produced by such delicate muslin-like membranes. Fig. 154 shows a

magnified view of the tips of a pair of the wings of one of the more delicate forms, which, although the

Fig. 153. Head of the larva of a dragon-fly.
Magnified to show the mask and true jaws below

nervures are frail, are strengthened one with another until they can be used with considerable muscular force, and so attain the speed necessary

to these insects when hawking after their prey ; for in their perfect state the carnivorous habit still remains with them.

When one of the larger kinds of dragon-fly is

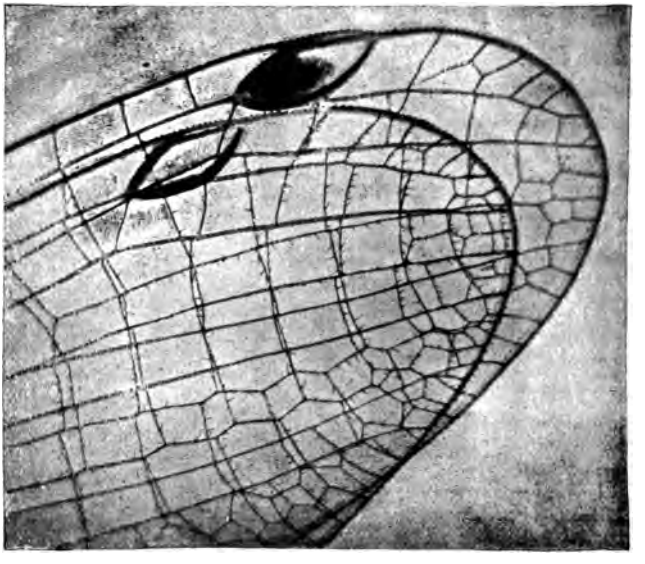

Fig. 154. Tips of the wings of a dragon-fly. Magnified to exhibit the structure

seen continually gliding and returning along some hedgerow or woodland glade, we may know it is overtaking and capturing smaller insects less swift of wing. These are often retained in the mouth until a sufficient quantity for a square meal is obtained, when the insect rests and masti-

cates its food. If, after capturing a dragon-fly on the wing, its mouth is opened and examined with a pocket lens, it is most frequently found to contain a mass of small insects, and sometimes half-chewed parts of larger insects. On recently

Fig. 155. The face of a dragon-fly.
Considerably magnified

capturing a dragon-fly and butterfly in the net at the same time—possibly the former was chasing the latter—I observed that the butterfly had a large piece cut abruptly out from both wings, which were closed together. Immediately afterwards I saw the missing portion rapidly disappearing into the mouth of the dragon-fly. The face

of a dragon-fly accords with its character; and one would think that, being suddenly presented to a helpless butterfly, with its large glaring eyes and terrible mouth (see Fig. 155), it might almost kill it with sheer fright.

CHAPTER X

WONDERFUL TEETH AND TONGUES

THE mouth of a snail is hardly the place where the seeker after beauty would expect to have his desires gratified. Yet we propose to make a little investigation in this apparently unsuitable direction.

That all people have not an insuperable prejudice to snails is evident from the fact that on the Continent—and it is said in some parts of England—the largest and fattest specimens of the edible or Roman snail, which we are about to discuss first, are considered a great delicacy when carefully cooked. But the snail is better equipped for eating than for being eaten: for we are told by our scientific friends that the creature possesses 140 rows of teeth, each row containing 151, thus giving a total of 21,140 teeth in the complete set. What an order for a dentist! But, unlike human beings, snails can altogether dispense with artificial aid; for as the front row of teeth wear away, the next

in order supply their place, new teeth being formed at the back to succeed the others.

Lest any incredulous reader should disbelieve the statement as to this vast number of teeth, I

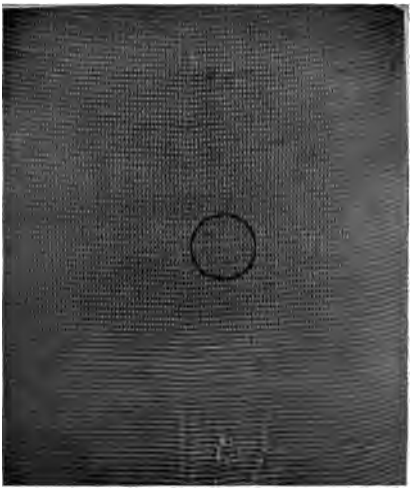

Fig. 156. Portion of palate of edible snail, showing its numerous teeth

would ask him to study the micrograph (Fig. 156) of a portion of the palate or tongue of a snail with its numerous rows of teeth, as seen by the microscope. This ribbon of teeth serves as a sort of rasp whereby our vegetables can speedily be cut down, as every gardener knows.

By means of these tiny and wonderful teeth

the individuality of the different genera and even species is recognised, so much differentiation of structure being found in the palates of the various molluscs. The contents of the small circle on

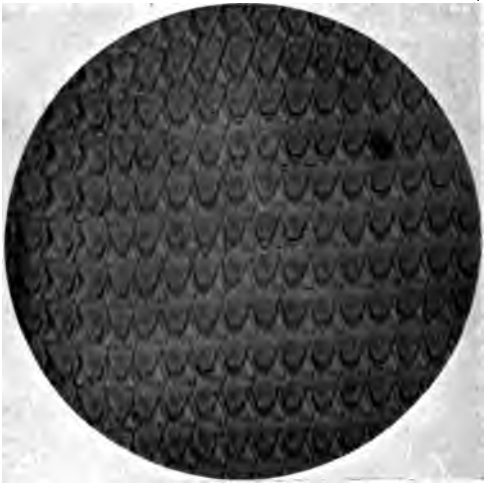

Fig. 157. The small circle on Fig. 156 contains these teeth

Fig. 156 I have photographed under considerably greater magnifying power (Fig. 157) to show the structure and arrangement of this marvellous dental display. These teeth are translucent, silicious, glossy, and beautiful to look upon when illuminated and seen under the microscope. Some species remind you of row upon row of

bayonets, needles, spikes, &c., while many are barbed along their trenchant edges. In Fig. 158 a beautiful example is given, showing numerous rows of various kinds of teeth on the same palate.

Fig. 158. Palate of snail showing different forms of teeth

Here we leave the snail family, and take up one of the slug species. The illustration in Fig. 159 is from a slug of carnivorous habits, which feeds on the common earth-worms. Worms, being tough and tricky, require a somewhat different digestive apparatus. On looking at our illustration, it will be seen that the teeth are long, slender, barbed

and curved, with their sharp points pointing inwards towards the gullet. The hopelessness of the return of a worm when once engulfed in this tube of about 2500 curved spines, furnished with

Fig. 159. Palate, or tongue, of a slug that eats worms

muscles to concentrate them upon the victim, can readily be imagined.

As a contrast to the tongues of the slug and snail, let us look at this organ in some insects, taking that of the common blow-fly, or blue-bottle as it is sometimes called, for my first example. Fig. 160 represents that wonderful organ which can often be seen by the unaided eye as a tiny bobbing object underneath the head

when the fly is feeding; but here its wonderful and marvellous structure is immensely magnified.

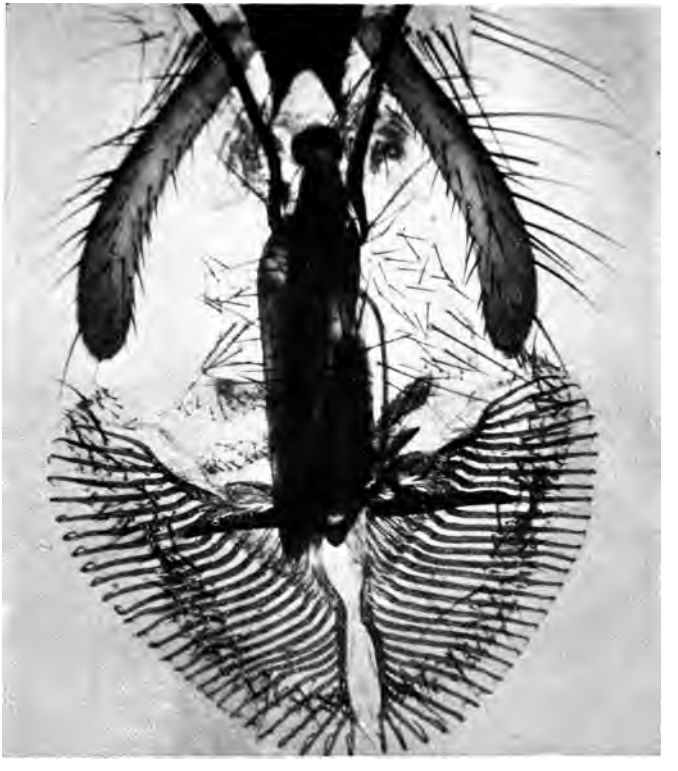

Fig. 160. Proboscis, or tongue, of common blow-fly

The blow-fly feeds by suction, not being accommodated like the snail or slug with teeth unlimited, and the complex series of channels or sucking

tubes converging to the two larger ones, each tube kept open by numerous horny half-rings, scarcely visible on the photograph, constitute together

Fig. 161. Proboscis of a hover-fly

with other internal parts a marvellous mechanism for facilitating the flow of fluid substances by capillary attraction towards the mouth. During the process, saliva is first secreted by the salivary ducts and rubbed about until some of the food-stuff is dissolved, after which it is sucked up again. The two bristly club-shaped organs on each side

are termed by scientists the *maxillary palpi;* their exact function is, however, doubtful without further evidence. They are undoubtedly organs of a sensitive nature, and may be associated with the sense of taste, or smell, or may perhaps indi-

Fig. 162. Tongue of a butterfly

cate a sense of which our human experience tells us nothing. At the base of these palps is the spot where the proboscis unites with the more internal parts. Such is the wonderful proboscis or tongue which the much-abused bluebottle possesses. In the chapter dealing with "Insects' Eggs" I had something to say concerning hover flies. At Fig. 161 is shown the proboscis of one of these flies, which are very active agents in the fertilisation of flowers. The proboscis in this

instance is long and well adapted for reaching the depths of flower blooms, for when these insects are fully developed they give up their larval

Fig. 163. Part of the mouth of a stag-beetle, showing its brush-like tongue

habits of devouring aphides, and become vegetable feeders upon honey and probably pollen.

Just one other example of a sucking proboscis, but with a different arrangement. The coiled watchspring-like form in Fig. 162 is the tongue of a common and beautiful butterfly. This re-

presents the tongue of butterflies generally, and is the organ which, when unrolled, seeks and gathers the sweet nectar or honey from the flower-blooms of summer. The small projections observed at the tip of the proboscis are generally supposed to be organs of taste, to aid in sampling the various drinks produced so abundantly by the flowers or the ripe fruits of our gardens. The thickness of this sucking-tube may be estimated roughly as about the same as a fine horsehair. It consists of two complex tubes side by side, capable of being separated and joined again at the insect's pleasure. The tubes are so firmly and perfectly united by minute hairs or bristles as to make an air-tight surface; the two tubes then acting as one.

Those of my readers who when "sugaring" for moths have had their "sugar" visited by the largest British beetle, known familiarly as the stag-beetle, and have seen, and possibly felt, its conspicuous mandibles, would probably imagine it to be a most predacious insect. However, its food is simply the juice of plants. Its horny and formidable mandibles serve only to wound the plant and so produce a flow of juice or sap for it to suck up with its double brush-like tongue, which may be seen in the centre of its mouth organs. Fig. 163 shows a portion of the mouth organs dissected out with this sap-sweeping tongue in the centre.

CHAPTER XI

SIMPLE WONDERS OF THE MICROSCOPE

PERHAPS some readers may possess microscopes and like to examine some of the marvels of minute nature, yet think perhaps that plant and insect dissection would be beyond their capabilities. But there is no need for despair: Fig. 164 gives a photograph of a speck or so of the dust often left, as most readers will have noticed, on the fingers after killing or handling a moth, simply laid on a glass slide and put under the microscope. The particular moth from which the scales were removed for the purpose of this illustration is the common Gold-tailed Moth frequent in our gardens during summer.

These scales of moths and butterflies are spread on each side of the colourless membrane of the wings, giving them their gorgeous colours; they overlap like the scales of a fish and make beautiful objects for the novice to examine *in situ*, or otherwise. In Fig. 165 an example of markings on a butterfly's wing is given the photograph being

taken from the underside of the wing of the common Wall Butterfly. It may also be said of these scales that, although of almost immeasurable

Fig. 164. Scales, or dust, from the wing of a moth

thinness, they are found to be composed of several layers, plain and ornamental; and have markings of such delicacy and beauty that opticians frequently use them as test-objects for obtaining accuracy in microscopic lenses.

The hairs of insects too are curious and well

worthy of inspection. Fig. 166 shows some taken from the familiar "woolly-bear" or larva of the Tiger Moth; and these, as the illustration shows,

Fig. 165. Markings on wing of butterfly, showing scales *in situ*

are not just the simple hairs they seem, but are beset with bristly fibrils along their length. Again the hairs from the large humble bee (Fig. 167) show that these branched hairs are not confined to caterpillars, but are sometimes found on perfect insects. And, as the scales of insects are but modified hairs, the leg of the Tiger Moth shown at Fig. 168 may be interesting as showing scales and hairs growing together.

The dried skins of various fishes also offer interesting and beautiful examples for the tyro to investigate with the microscope. Fish scales are

Fig. 166. Hairs of "woolly-bear" caterpillar

contained in distinct membranous sacs of the cutis or skin proper; and above the scales is a fine membrane or skin layer quite distinct from the cutis, although the rough scaly bodies of some fishes scarcely appear to the unaided eye to be thus covered. The dried skins of the dog-fishes, which latter are of common occurrence in British

seas, and of little commercial value, provide pretty objects for the microscope; Fig. 169 illustrates this. The skin of these fishes is sometimes used

Fig. 167. Hairs of a humble bee

as a substitute for sand-paper, and employed by joiners for polishing the surface of fine woods to show up the grain.

But, as every microscopist may not meet with a dog-fish, let us glance at other and more familiar examples of fish-skins. For instance, Fig. 170 shows a small portion of the skin of the sole, a

beautiful and easily obtained object. Again, the skin of the eel may likewise be considered. In this instance the scales do not project above the

Fig. 168. Leg of a Tiger Moth

surface, hence the popular impression that the slippery eel has no scales. However, a fragment of the dried skin is shown in Fig. 171 sufficiently

magnified to reveal its scales. These are covered externally with the fine membrane which contains the pigment cells. These can be seen as dark-coloured spots amongst the scales. The scales

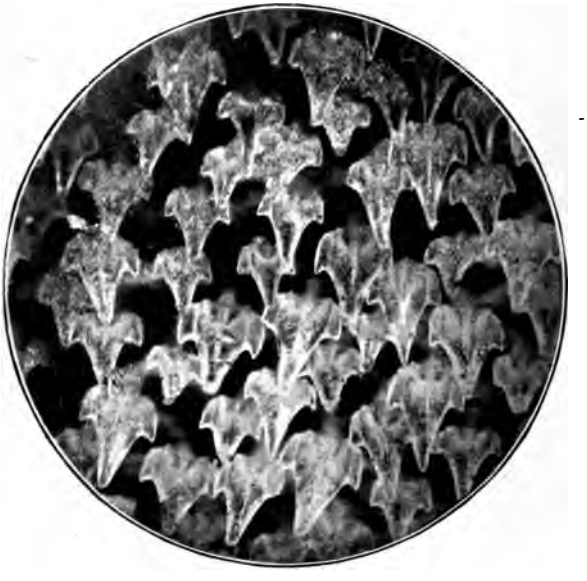

Fig. 169. The scaly skin of the dog-fish

themselves can be removed, and are composed of a number of rounded or angular bodies impregnated with calcareous matter. One of these scales, considerably magnified, is shown in Fig. 172. Those readers who keep gold-fish

may profitably examine the scales of these; and one is shown in Fig. 173.

If the taste of my readers is not with the

Fig. 170. Skin of a sole

fishes, they may readily turn to the birds, whose feathers present many interesting examples of minute details.

Feathers may be regarded as composed of doubly or triply pinnatifid hairs, and consist of the "quill" or central axis which carry the "barbs," which latter together form the "vane."

The barbs lie opposite to each other on each side of the shaft, and fit so closely together as to form a compact and flattened plane, except that each barb has its edge arranged so as to cover the

Fig. 171. The skin of the eel, showing its scale

base of the barb preceding it. At the tips of the barbs issue fine and often long cilia or thread-like lashes, which interlace with the neighbouring barbs. Under high magnifying powers these threads are seen to possess various contrivances, such as tiny hooks, knots, &c., arranged so that the edge, terminating with a row of hooks, meets at angle with the plain bar-like edges of several

of its neighbours, so that the whole become converted into a flat elastic web or plane, by means of which the bird can exert pressure upon the air. These tiny hooklets, although so minute, are therefore very important.

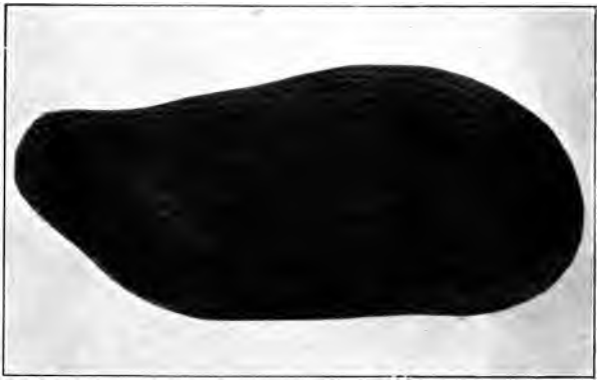

Fig. 172. A scale removed from the skin of an eel

Every one has on handling a flattened feather found how difficult, if not quite impossible, it is after once disarranging the barbs to rearrange them again; and Figs. 174 and 175 will explain how beautifully these barbs are interlaced, and how when once disordered it is only by chance that they can be rearranged. The tiny hooklets would require very much higher powers to examine, being extremely delicate.

All feathers are not arranged on this plan, in fact different species of birds have their feathers adapted to their special circumstances in life; for example, the ostrich having developed running

Fig. 173. Scale from a gold-fish

propensities in preference to flying, has lost the character of flying feathers and developed the familiar waving plumes of commerce. A portion of a feather of an ostrich is illustrated in Fig. 176, showing the loose barbs or fibrils, which, on comparison with those of the humming bird and

condor previously shown, will quite account for their difference in outward appearance.

Another example from the same order of flight-

Fig. 174. A portion of the feather of a humming bird, showing how the barbs interlace

less birds is given in Fig. 177. This represents the feather of an emu, whose plumage somewhat resembles long fur as it hangs down on either side of the bird's body from the central parting line which runs down the middle of the back. Penguins—birds which dive and swim instead of flying—develop but small and scaly feathers

Another curious example of a feather is given in Fig. 178. The original was taken from the owl, whose plumage is soft and downy; and why?

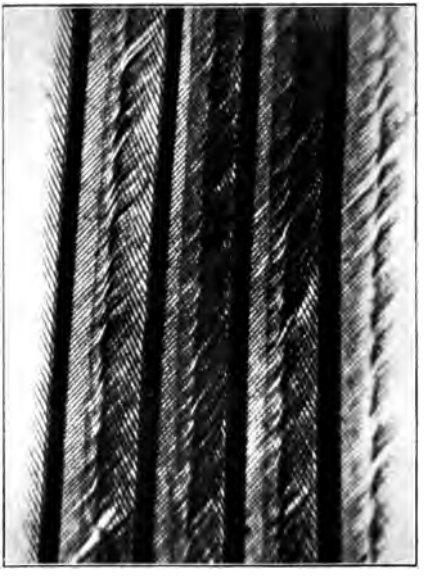

Fig. 175. Feather of condor, also showing interlacing of the fibrils

The owl hunts its prey by night, and as field mice and small birds are quick in their movements if alarmed, the owl is provided with loose and soft plumage, so that in flight it is almost noiseless.

Having glanced at some insects' hairs and birds' feathers, we may, in conclusion, consider

some hairs of mammals. Hairs partake of the same structure as the skin, and do not, as their appearance suggests, arise from just

Fig. 176. Feather of ostrich, showing loose fibrils

the surface. They originate in follicles or pouches which penetrate into the different layers of the skin, and they may be regarded as modified skin structures. A section cut through the skin of a mouse is shown in Fig. 179, and this will give a better idea than any description

Fig. 177. Feather of an emu

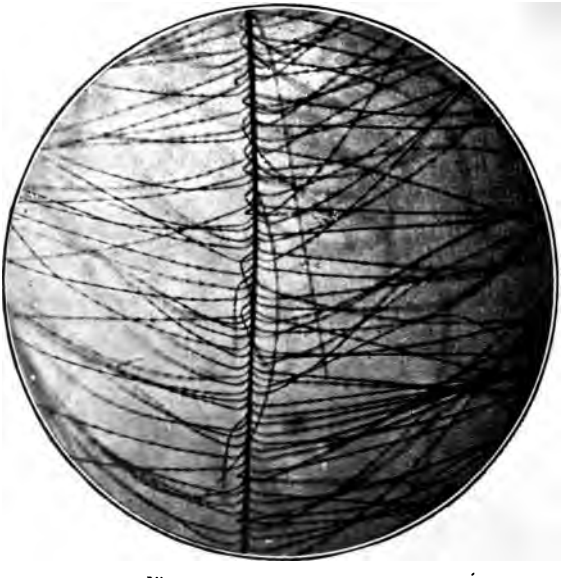

Fig. 178. Feather of an owl

of how the base or bulb of the hair is embedded in the skin and passes out to the surface through a kind of little sheath. The human skin when

Fig. 179. A section cut through the skin of a mouse to show how the hairs originate from bulbs below the surface skin

seen in section shows similar hair development.

The colour of the hair is derived from pigment granules contained in a layer of cells between the outer cuticle layer and the true skin. These granules are very minute and appear abundantly in healthy hair, and are mostly arranged in lines between the elongated and elastic cells of the cortex or exterior of the hair.

The hairs of the mouse and other rodents exhibit beautiful and interesting examples of hair structure on account of the arrangement of their air-cells. The mouse hair, Fig. 180, shows an

Fig. 180. Mouse hair

arrangement in the larger hairs of three longitudinal series of cells, while the finer hairs have but one or two rows of cells.

Human hairs do not present such pretty examples as some of those of the lower animals. A few shavings from the human beard are shown at Fig. 181. These it will be observed present a dark appearance along their centres, and this is

not due to the colouring pigment, but is owing to the air contained in them. The colouring

Fig. 181. Shavings from the human beard

matter is contained in the outer or cortical cell layer.

Most animal hairs make interesting objects for microscopic investigation, and by a little practice sections of hairs may be cut with a sharp razor, after tying a little bundle together and dipping in glue and allowing to dry, afterwards dissolving off the glue. Hair sections sometimes are surpris-

ingly pretty. Fig. 182 illustrates a curious type, being several sections cut through the whisker hairs of a lioness. In Fig. 183 is another example from the hairs of one of the American peccaries,

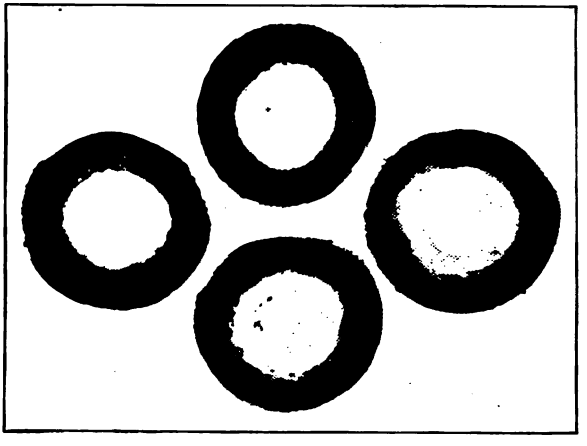

Fig. 182. Section of the whisker hairs of a lioness

which are not unlike small pigs in their appearance and habits. Lastly, sections are shown from the hairs of the African elephant in Fig. 184, although this great creature seldom has many hairs to spare for scientific purposes, only having a fringe of a few long hairs at the extremity of its tail.

And now that we have glanced at many and various kinds of plant and animal organisations, and learnt, I trust, that all are wonderfully and

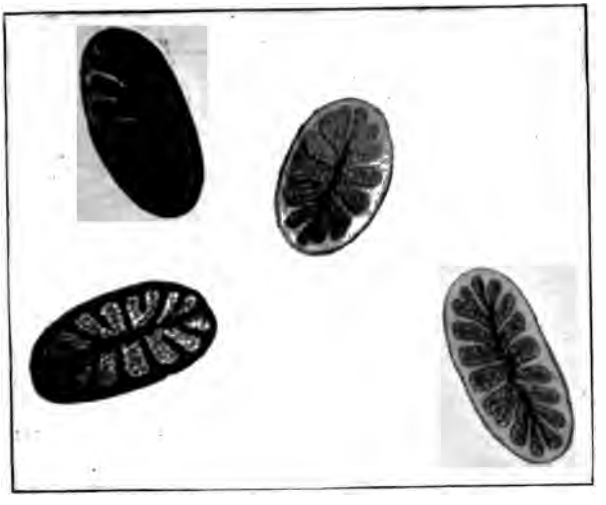

Fig. 183. Sections of the hairs of an American peccary

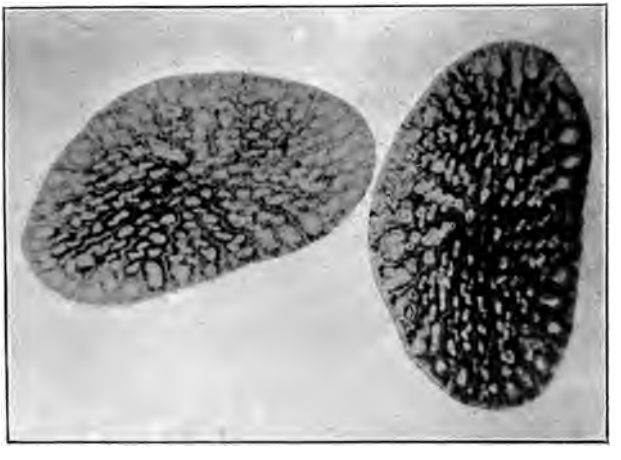

Fig. 184. Sections of the tail hairs of the African elephant

wisely arranged, even in those organs and functions which lie beyond our ordinary vision and understanding, surely our minds should be ennobled, and our interests in Nature's marvels widened and elevated.

If this little volume has helped only one reader to a better conception of these minute marvels it has served a not unworthy purpose.

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